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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CX.—No. 2856.] *LONDON: FRIDAY, SEPTEMBER 24, 1920.* [*Registered at the General Post Office as a Newspaper.*] [PRICE 1s 2d. BY FOREIGN POST 1s. 5d.

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See Full Page Advt., page 83, Sept. 17.

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See Full Page Advertisement, Sept. 17.

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See half-page Advertisement, page 97, Sept. 3.

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R. P. G. WILLIAMSON,
Director of Education.

Education Offices,
Town Hall, Hanley,
Stoke-on-Trent.
28th August, 1920. J 514

Northampton Polytechnic INSTITUTE,

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EVENING TECHNICAL COURSES
In all Branches of
MECHANICAL & ELECTRICAL ENGINEERING
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Principal. J 919

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PADDINGTON TECHNICAL INSTITUTE, Saltram Crescent, W. 9 (Electrical and Mechanical).
REGENT STREET POLYTECHNIC, Regent Street, W. 1 (Mechanical and Electrical).
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WESTMINSTER TECHNICAL INSTITUTE, Vincent Square, S.W. 1 (Civil and Gas).
WOOLWICH POLYTECHNIC, William Street, Woolwich, S.E. 18 (Mechanical and Electrical).

The fees are small, and in some cases trade students under 21 years of age and otherwise eligible are admitted free.

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JAMES BIRD,
Clerk of the London County Council. J 731

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Systematic COURSES of INSTRUCTION in STRUCTURAL ENGINEERING, SURVEYING and LEVELLING, HYDRAULICS, SPECIFICATIONS, QUANTITIES and ESTIMATES, ENGINEERING MATHEMATICS, etc., will begin on 27th September, 1920. Students are enrolled during the preceding week.

In addition, special advanced sessional courses of lectures will be delivered on Thursdays and Fridays from 6.30 to 8.45 p.m., as follows:—

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These courses are intended for Civil Engineers and others well grounded in the theory of Structural Design, but the general principles of structural design bearing on the special problems involved will be considered throughout the course.

Full prospectus giving particulars of the courses, fees, etc., may be obtained on application at the Institute.

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JOHN J. JACKSON, B.A.,
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The Metropolitan Water Board invite

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The Material may be seen at the address stated at any time between 9 a.m. and 4 p.m. on week days (Saturday excepted) on application to the Storekeeper, M.W.B. (Battersea) Works, Kirtling Street, Nine Elms Lane, Battersea.

A schedule containing particulars of the material together with Tender Form and Conditions of Contract may be obtained from the Chief Engineer by personal application or upon forwarding a stamped addressed envelope.

Tenders, which must be on the official form, enclosed in sealed envelopes, addressed to "The Clerk of the Board, Metropolitan Water Board, 173, Rosebery Avenue, Clerkenwell, E.C. 1.," endorsed "Tender for Disposal of Scrap Metal, &c." must be delivered at the offices of the Board not later than 4 p.m. on Wednesday, 6th October, 1920.

The Board do not bind themselves to accept the highest or any Tender.

A. B. PILLING,
Clerk of the Board.

Offices of the Board,
173, Rosebery Avenue,
Clerkenwell, E.C. 1.
20th September, 1920. J 909

FOR SALE.

THE HARROW ELECTRIC LIGHT & POWER CO., LTD., invite

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Three 60 Kw. Willans-Crompton GENERATING SETS, 460 volts, steam pressure 160 lbs., including one Spare Armature.
One Willan-Crompton STEAM BALANCER, 37 amps., 310 volts, suitable for three wire system 440 and 220 volts.
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Four Babcock WATER TUBE BOILERS, 180 lbs. working pressure; two 30 tubes arranged for hand firing, two 31 tubes fitted with chain grate stokers, 5 HP., 440 volts, Motor and Starter.
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Sundry Countershafting, Steam Pipes and Valves.

Further particulars and permit to inspect may be obtained from the undersigned or from the Consulting Engineers to the Company, Messrs. MAY & HAWES, 36, Victoria Street, Westminster.

W. H. BISHOP,
Secretary and Manager.

College Road,
Harrow. J 904

TO CONTRACTORS.

BELFAST WATER WORKS.

MOURNE SCHEME.

CONTRACT A.

For the Construction of the "SILENT VALLEY" STORAGE RESERVOIR, &c.

The Belfast City and District Water Commissioners are prepared to receive

Tenders from Competent

CONTRACTORS for the CONSTRUCTION of the "SILENT VALLEY" STORAGE RESERVOIR, &c., in the MOURNE MOUNTAINS, County Down, having an Earthen Embankment about 1,500 ft. long and 90 ft. high, and a storage capacity of 3,000 million gallons, with an Outlet Tunnel, Waste Channel, and other auxiliary works, also the construction of a temporary Works Railway.

The Contract Drawings and Specification have been prepared by the Commissioners' Chief Engineer, Mr. P. W. M'Cullough, M.Inst.C.E., Water Office, Royal Avenue, Belfast, and may be inspected at his Office on any weekday (except Saturday), between the hours of Ten a.m. and Five p.m.

Duplicate Copies of the Specification and Form of Tender, &c., may be obtained from the undersigned upon payment of the sum of Five Guineas. This sum will only be repaid by the Commissioners after the receipt of a *bona fide* Tender which has not been withdrawn.

On the Tuesday and Friday of each week, commencing with Tuesday, the 28th inst., an Assistant Engineer will meet Intending Contractors at the Engineer's Office, at Ten o'clock forenoon, and accompany them to the site of the proposed Works.

Tenders, sealed and endorsed "Tender for Silent Valley Storage Reservoir, &c.," must be delivered by registered post, and addressed to the undersigned, not later than Three p.m. on Wednesday, 3rd November, 1920.

The Commissioners do not bind themselves to accept the lowest or any Tender, nor will they be responsible for any expenses incurred in making out a Tender.

W. I. QUINN,
Secretary,
Water Office, Royal Avenue,
9th September, 1920. Belfast. J 787

TO CONTRACTORS.

BELFAST WATER WORKS.

MOURNE SCHEME.

CONTRACT A.

For the Construction of the "SILENT VALLEY" STORAGE RESERVOIR, &c.

SCHEDULE OF QUANTITIES.

A Detailed "Schedule of

QUANTITIES" has been prepared by me for the above Extensive Storage Reservoir and other Works in the Mourne Mountains, County of Down. Contractors wishing to Tender for this work will be supplied with Printed Copies of the "Schedule of Quantities" on application and payment to me of the sum of Three Guineas per Copy, which sum will not be repayable.

ADHESON FERGUSON,
Quantity Surveyor,
Scottish Provident Buildings,
9th September, 1920. Belfast. J 788

COMMISSIONERS OF IRISH LIGHTS.

NOTICE TO SHIPBUILDERS.

The Commissioners of Irish Lights are prepared to receive

Tenders for the Construction

of an IRON and STEEL LIGHTSHIP. Dimensions: 102 ft. by 24 ft. 3 in. moulded, and 12 ft. 6 in. depth of hold.

Firms who will undertake to submit a bona fide quotation for this work may obtain drawings, specifications and Forms of Tender on application to the undersigned.

Tenders sealed and endorsed "Tender for Lightship," must be posted so as to reach the Secretary's Office, Carlisle Buildings, D'Olier Street, Dublin, on or before Thursday, the 28th day of October, 1920.

The Commissioners do not bind themselves to accept the lowest or any Tender.

By Order,
H. G. COOK, Secretary. J 901

Tenders are Invited by the

MINISTRY OF PUBLIC WORKS, CAIRO, for the SUPPLY of ONE STERN WHEEL STEAMER.

Tenders must reach the office of the Public Works Department, Cairo, not later than 1st December, 1920.

Conditions of Tender, Form of Tender and Specification can be obtained (price 5s. 2d.) at the office of Sir A. L. WEBB, K.C.M.G., Queen Anne's Chambers, Broadway, Westminster, S.W. 1. J 905

APPOINTMENTS OPEN.

HUDDERSFIELD TECHNICAL COLLEGE.

An Assistant Lecturer in

ELECTRICAL ENGINEERING is REQUIRED at once. Commencing salary, £200. Applications should be addressed to the PRINCIPAL, Technical College, Huddersfield, as soon as possible.

T. THORP, Secretary. J 935

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The Council invite

Applications for this Post.

Salary £300, increasing to £400 by annual increments of £50. Full particulars may be obtained from the REGISTRAR, to whom applications must be made on or before 27th September. J 903

HULL EDUCATION COMMITTEE.

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An Assistant Lecturer in

Mechanical Engineering is REQUIRED at the above College, mainly to devote his time to Mathematics and Laboratory Work in Mechanics and Engineering Science.

Salary £350 to £450 with additional payment for Evening Classes. Commencing salary according to teaching experience.

Forms of application may be obtained from the undersigned on receipt of a stamped addressed foolscap envelope and must be returned so as to reach these offices not later than Monday morning the 4th October, 1920.

J. T. RILEY,
Director of Education.

Education Offices,
Albion Street,
Hull, 17th September, 1920. J 880

DUDLEY EDUCATION COMMITTEE.

DUDLEY TECHNICAL SCHOOL.
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Candidates must have served in some branch of His Majesty's Forces during the late War, unless satisfactory reasons for not having done so can be furnished. J 889

SHIP RESISTANCE AND THE RAMUS PRINCIPLE.

By A. W. JOHNS, C.B.E., R.C.N.C., Mem. Council I.N.A.

THE Reverend Charles Meade Ramus, at the time Rector of Playden, Rye, Sussex, was the first in this country to suggest the adoption of stepped inclined planes as the shape of the bottoms of ships, with a view to increase the speed. His suggestion was sent to the Admiralty in April, 1872, and was referred for experiment and report to Mr. W. Froude, who was then engaged at his model tank at Chelston Cross, Torquay, on those researches on surface friction and ship resistance, which are the foundations of the methods now generally employed. Mr. Froude's report showed that at the time the adoption of the proposal was impracticable for the object in view. The progress in engineering science by the introduction of the internal combustion engine and its rapid improvement, has, however, permitted of the adoption of the Ramus proposal during the last 10 or 15 years in the construction of hydroplanes or skimmers and in the floats of sea planes. The Reverend Mr. Ramus died in 1896 and thus had not the satisfaction of seeing the practical adoption of the proposal which he had urged in 1872 with so much pertinacity.

The whole of the correspondence between Mr. Ramus and the Admiralty, together with Mr. Froude's report on the proposal, were published as a Parliamentary Return in 1873 or early in 1874. From the point of view of ship resistance, this Return is of some historic value, for not only does it deal with the Ramus proposal, but it was the first report and also appears to have been one of the first published accounts of those methods which Mr. W. Froude adopted for the determination of ship resistance from the results of experiments on models. The report is dated September 4, 1872, and was written between the two reports on surface friction, which are dated August 10 and December 13. The towing experiments on the *Greyhound* were made in 1871 and the report on them is dated March 31, 1873, but it and the two surface friction reports were not published until the middle of 1874, after the Ramus Return had been laid before Parliament. All Mr. W. Froude's reports are characterised by great clearness of writing, but the Ramus report is especially clear, since, when writing it, he knew he had to cater for the non-technical reader. The account of these experiments and their results are generally omitted from books dealing with ship resistance. They are, however, of great interest to naval architects, especially now that the principle is in practical application.

The return opens with a latter dated April 8, 1872, from the Reverend Mr. Ramus to the Admiralty, in which he stated that some years previously it became manifest to him that the speeds of ships might be immensely increased by an extensive alteration in the shape of their hulls. This change was based on mathematical and mechanical principles and would, he firmly believed, at least double the speed of steam vessels. He asked for an assurance that the discovery should be acknowledged as emanating from him and, on receipt of this, would forward his proposals. Two days later he had an interview with Mr. Nathaniel Barnaby—the Chief Naval Constructor—and a joint memorandum was forwarded by them to the Controller of the Navy. From the sketches which accompanied this memorandum it would appear that numerous inventors had repeatedly suggested the use of one inclined plane* for the shape of the bottoms of ships. The Ramus proposal was two equally inclined planes with a step between at amidships the step being perpendicular to the planes and extending to the waterline when the vessel was at rest. This memorandum was confirmed by a letter of the same date from the Rev. Mr. Ramus, in which he pointed out the following advantages of his proposal:—

1. The resistance of the water increased very little with increased speed.

2. Breadth of beam was no disadvantage whatever to the speed, but added to stability and enabled the vessel to draw very little water.

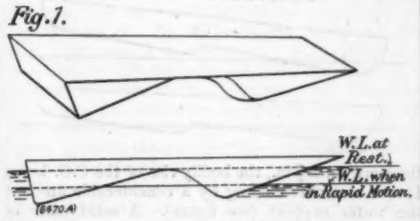
3. There was no limit to the speed, except the resistance of the air and a speed of 30, 40 or 50 miles per hour by sea was rendered practicable.

He considered the correct angles of the planes, the proper distance between them, the best proportion of length to breadth and any other particular must properly form the subject of continued experiments. The two figures accompanying the letter are shown below.

The correspondence was referred to Mr. W. Froude and he was requested to include the form amongst those he was proposing to subject to experiment. In a letter dated April 12, the Rev. Mr. Ramus reported the results of some experiments he had himself carried out with a model 31 in. long, 11¼ in. broad, 3 in. draught, weighing 9¼ lb. with planes at 10 deg. inclination, and drawn at speeds up to 15 miles per hour. He stated that at 10 m.p.h. the force required to draw the model sensibly diminished and this he considered was due to the lift of the model. At 15 m.p.h. the model skimmed the water with only the after edges of the planes in contact. He proposed to carry out further experiments at 30 m.p.h. and higher speeds, using rockets as the propulsive agent.

Some correspondence then took place as to the angle of inclination to be given the planes for the model experiments at Torquay. Mr. Froude requested that particulars of the calculations from which the angle had been obtained should be

Fig. 1.



forwarded to him. These apparently were not available. The first rough sketch supplied had shown 10 deg. as the angle. A later letter from Mr. Ramus gave 8 deg. but this was qualified by the statement that the angle varied with the speed. Later he stated that he found 2 deg. or 3 deg. was the best for all speeds.

On May 22 Mr. Ramus forwarded drawings to the Admiralty showing his proposals for a vessel 352 ft. long, 50 ft. broad, 7 ft. draught, and 2,500 tons displacement. The maximum breadth was maintained for the after 280 ft. of length, the forward end in plan being similar to an ordinary ship. The stern in plan was very slightly rounded. The planes were each 150 ft. long, with a slope of 1 in 50, the step being amidships and 3 ft. deep. The stem was vertical, but the after end of after-plane was rounded up to meet the deck line. The engines were 1,500 h.p., driving paddle wheels of 44 ft. diameter, projecting about 2 feet below the maximum draught. The speed estimated by the designer was 30 m.p.h. in ordinary weather, and on extraordinary occasions 50 m.p.h. to 60 m.p.h.

In a letter dated July 5 some modifications were suggested. 21 ft. were added forward, making the total length 373 ft. and the maximum breadth was carried along the whole length. The fore foot was curved from the fore end of foremost plane to the deck extremity, the designer claiming that by so shaping the bow the ship would tend to rise as the bow met the waves instead of cutting through them. In constructing the models Mr. Froude used this modified form, the freeboard being slightly reduced with a consequent reduction in total length of the ship of 3 ft.—*i.e.*, the overall length was 370 ft. The step in the ship and in the models was rather more gradual than is now adopted, the end of the forward plane being given a slightly rounded shape in profile view.

The model experiments were carried out in July, the Reverend Mr. Ramus being present. According to the report he was satisfied that the experiments were conducted with a careful endeavour to give full effect to the principle on which he relied, although the results were not in accordance with his expectations. In a letter written after receipt of a copy of Mr. Froude's report, Mr. Ramus confirmed the first part of this statement.

Mr. Froude's report is divided into two parts The first deals with the dimensions, &c. of the models used; a description of the experiments; an explanation at some length of the methods used in obtaining the ship results from those of the models and the methods of constructing the diagrams. The second part gives a summary of the results obtained, the conclusions to be drawn therefrom, and includes an investigation into the forces, &c. operating on bodies constructed according to the proposals of Mr. Ramus.

Several figures accompany the report. These include curves of total and frictional resistance for the models, the former as determined by the experiments and the latter as calculated from the data obtained from the experiments on planks; curves showing the rise of the bow and sinkage of the stern as the speed increased; sketches showing the behaviour of the models and the wave profiles at various speeds; resistance and effective horse-power for the proposed ship of 2,500 tons; and finally a sketch of the latter.

Two models of the 2,500-ton Ramus ship were used in the experiments, one to a scale of $\frac{1}{8}$th and the other $\frac{1}{10\frac{1}{2}}$th full-size. The larger was 10·3 ft. long and weighed 120 lb., the smaller 3·43 ft. long, $5\frac{5}{8}$ in. breadth, $\frac{7}{8}$ in. draught and weighing 4·44 lb. The two were used for the purpose of testing the law of similitude and by comparison of the results to obtain any correction which might be necessary in passing from the model results to the full-sized ship. A second reason was that the mechanical arrangements for recording the resistance only permitted of the larger model being run up to a maximum speed of 950 ft. per minute, corresponding to about 57 knots in the ship, whereas, with the smaller model a speed of 1,250 ft. per minute, corresponding to nearly 130 knots could be attained.

A third model of the same extreme dimensions, and of the same weight, as the larger Ramus model was also made and tried. The form given this model was that of a ship of ordinary form for these dimensions. This model was termed the Pro Ramus.

The remainder of the first portion of the report is devoted to explaining the law of comparison; the reason and method for allowing for the differences in surface friction for different lengths of surfaces; and to explaining the construction of the diagrams. In the second part of the report, the results are analysed. This portion contains two tables, one of which shows the resistances of the Ramus and Pro Ramus ships of 2,500 tons displacement at the same speeds and the other the effective horse-powers at certain speeds for the Ramus ship. The first table is given below:—

Speed. ..	10 knots.		12 knots.		17·8 knots.		52 knots.		130 knots.	
	Resistance.		Resistance.		Resistance.		Resistance.		Resistance.	
——	In Tons.	Per Ton of Displacement.	In Tons.	Per Ton of Displacement.	In Tons.	Per Ton of Displacement.	In Tons.	Per Ton of Displacement.	In Tons.	Per Ton of Displacement.
Ramus	14·3	$\frac{1}{175}$	23·6	$\frac{1}{106}$	73·2	$\frac{1}{34}$	381·0	$\frac{1}{6\cdot57}$	509·	$\frac{1}{4\cdot91}$
Pro Ramus	8·0	$\frac{1}{313}$	13·4	$\frac{1}{187}$	43·0	$\frac{1}{58}$	297·0	$\frac{1}{8\cdot42}$	—	—

The resistance of the Pro Ramus at 130 knots is not given, but is about 1,500 tons or three times that of the Ramus. Equality of resistance of the two ships occurs at about 65 knots. Below this speed

* Such a form was patented by Joseph Apsey in 1852, No. 225. In this patent the front half of the bottom and sides forward were inclined from keel to waterline.

the Pro Ramus resistance is less than the Ramus, but, above this speed is greater and at 130 knots is three times as great. The Pro Ramus form is not, however, a good form for high speeds, since the ratios of length to breadth (370 to 50) and breadth to draught (50 to 7) are very abnormal. A destroyer of the same length would at 52 knots have a resistance of about $\frac{1}{13}$th the displacement in place of $\frac{1}{7.5}$th. The speed at which equality of resistance occurs and which for the two ships in the table is 65 knots, would be appreciably higher in the case of a ship of destroyer form and the Ramus. Mr. Froude also included in the table the resistances of a Great Greyhound of twice the dimensions of the original. This larger vessel was 340 ft. long and of 9,820 tons displacement and at 10 knots, 12 knots and 17·8 knots, has resistances of $\frac{1}{21\cdot4}$, $\frac{1}{13\cdot1}$ and $\frac{1}{11\cdot6}$ respectively of the displacement.

The second table, given below, shows the effective horse-power—resistance in pounds multiplied by speed in feet per minute and divided by 33,000—of the Ramus ship :—

Speed in Knots.	Effective Horse-Power.			
	Due to Total Resistance.		Due to Air Resistance alone.	
	Total.	Per Ton of Displacement.	Total.	Per Ton of Displacement.
10	1,000	·4	—	—
20	14,000	5·6	—	—
30	44,000	17·6	—	—
40	83,000	33·2	—	—
50	124,000	49·6	1,020	·41
60	172,000	68·8	1,760	·70
90	308,000	123·2	5,950	2·38
130	455,000	182·0	17,800	7·12
240	—	—	112,500	45·00

The air-resistance figures were obtained from information given by the Greyhound trials and presumably include resistances of masts, rigging, funnel, &c. The resistance is taken to vary as the square of the speed an assumption which, in view of later experiments and information will give too high a value especially when it is remembered that the speed at which it was determined in Greyhound was relatively very low.

At 65 knots, the speed at which equality of resistance and power occurs for the Ramus and Pro Ramus forms, the effective horse-power is about 192,000 or 77 per ton of displacement, which, with a propulsive coefficient of 45 per cent., gives 170 i.h.p. per ton.

In 1872 warship-propelling installations developed 6 i.h.p. to 7 i.h.p. per ton of weight. Probably those in merchant ships were heavier. Taking 7 i.h.p. to the ton, the weight of such an installation in the Ramus ship for 65 knots speed would be 24 times the displacement. The lightest propelling installation at the time was probably that fitted in the yacht Miranda, which gave about 36 i.h.p. per ton. Even with a similar installation in the Ramus ship the weight required for it would be nearly five times the displacement. The impracticability of the Ramus proposal at the time was therefore clearly manifest.

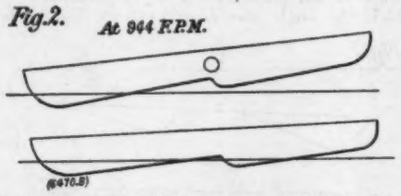
The rapid progress made in the development of the internal combustion engine during the last few years has, however, considerably reduced the weight of propelling installations and also the fuel required. The 36 i.h.p. per ton of machinery installation of the Miranda of 1872 has now being increased to over 1,000 per ton in aeroplane engines and thus has rendered the Ramus principle an easily practicable proposition for small vessels. For the 2,500 ton ship it will remain impracticable until large powered and very light engines are available.

Mr. Froude's only object was to test the practicability of the proposal and he conclusively proved, as indicated above, that it was not capable of adoption at the time. He could not foresee, the great progress in engineering science which was to take place 30 or 40 years later. No attempt was therefore made by Mr. Froude to improve on the suggested form of Mr. Ramus with a view to reducing the resistance. The latter would have required to be reduced by nearly 90 per cent. to render it of practicable application.

For these reasons Mr. Froude made no remarks on some of the features of the results of the experiments which, now that the principle is used, are of more interest. One of the diagrams accompanying the report shows the rise of bow and fall of stern of the models as the speed increased. This was the first of such observations ever taken and is now one of the standard observations and records made for all models. From the movements of bow and stern the motion of the centre of gravity at the middle of length can be ascertained. For the smaller model and for speeds below 440 ft. per minute the sinkage of stern was more than the rise of bow and the vessel sank bodily, as is the case with most models for all speeds. At 300 ft. per minute this fall of the C.G. was $\frac{1}{4}$ in. and at 400 ft. per minute $\frac{1}{32}$ in. At 440 ft. per minute the model began to rise bodily, the bow rising a greater distance than the stern fell. At 500 ft. per minute this bodily rise was $\frac{1}{16}$ in., the bow rising 1·4 and the stern sinking 1·2 in. At 600 ft. per minute the corresponding figures are $\frac{1}{16}$ in., $2\frac{1}{4}$ in. and 1 $\frac{3}{4}$ in. The maximum draught being $\frac{7}{8}$ in. when the model is at rest, at 600 ft. per minute the model was raised 60 per cent. of the draught.

At 944 ft. per minute a curious and paradoxical result was observed. For the first portion of the run along the tank, the model skimmed the water with only the after edge of the after plane in contact. In this position the bow had been raised $3\frac{1}{8}$ in. and

Fig.2. *At 944 F.P.M.*



(6476.B)

the stern sunk $\frac{7}{8}$ in., the bodily rise of the C.G. being $1\frac{1}{2}$ in., and overhanging by a considerable amount the water support (see figure). A solid mass of dead water was formed at and became attached to the stern during this portion of the run, and this becoming detached, the model settled down for the remainder of the run to a position in which the after edges of both planes were in contact with the water. In this second position the rise of bow was 2·44 in. and sinkage of stern 1·08 in., the rise of the centre of gravity being ·53 in. or 70 per cent. of the draught when at rest. According to the curve of resistance the unstable position of the model, *i.e.*, that at which the deadwater forms at the stern, commences at about 600 ft. per minute. It was not noticed in the larger model for which the speed corresponding would be about 1,040 ft. per minute, the highest speed attained being 950.

At 944 ft. per minute the resistance of the smaller model over the first portion of the run was 9 per cent. greater than for the second portion. As the surface friction resistance must have been less due to the smaller surface in contact the extra resistance involved by the deadwater must have been much greater than this percentage. Mr. Froude remarks that in the cases of other bodies tried in the tank the discharge of dead water from the body in motion had been accompanied by a marked diminution in resistance as in this case.

The angles of trim taken up by the larger model, as measured, are approximately the same as those of the smaller at corresponding speeds. The larger model begins to rise bodily at about 760 ft. per minute, which corresponds to 440 ft. per minute for the smaller.

Turning next to the total and skin friction resistance curves for the smaller model, the table given in the next column shows how these and the residuary resistance vary with the speed.

The frictional resistance curve does not extend above 1,000 ft. per minute, and is given only for the case of the model moving with no dead water behind it. The double figures in the fourth column are the ordinates of the resistance curves one with dead water and the other without it, the larger value at any speed being for the former.

The variation of the skin friction resistance with the speed is noteworthy. At 400 ft. per minute it is ·4 lb., whilst at 800 ft. per minute it is ·80 lb., and at 1,000 ft. per minute, ·84 lb. For such short surfaces this resistance varies with the square of the speed and the results show that at 800 ft. per minute only one half and at 1,000 ft. per minute only one-third the area at 400 ft. per minute is in contact with water.

The actual method of obtaining the wetted area for calculating the skin resistance is not explained by Mr. Froude, but, as careful records of the water level on the model were taken, it is presumed these were utilised.

The residuary resistance is a maximum at a speed of between 600 ft. per minute and 700 ft. per minute, and above the latter is slowly decreasing.

Speed Feet per Minute.	Skin Friction Resistance. Lbs.	Residuary Resistance. Lbs.	Total Resistance. Lbs.
300	·225	·25	·475
400	·40	·34	·74
500	·56	·41	·97
600	·68	·49	1·17
700	·75	·49	1·24
			1·28
800	·80	·48	1·28
			1·35
900	·82	·48	1·30
			1·40
1,000	·84	·46	1·30
			1·45
1,100	—	—	—
			1·5
1,200	—	—	—
			1·6

The total resistance curve is practically a straight line between 200 ft. per minute and 450 ft. per minute, except for a slight hump which extends from 200 ft. per minute to 350 ft. per minute, and has a maximum value at 240 ft. per minute where the resistance is about 9 per cent. greater than that to the straight line. This speed corresponds to that of a wave of the same length as the model. At 440 ft. per minute, the speed at which the model commences to lift, the resistance curve begins to fall below the straight line and becomes concave to the speed axes. At 600 ft. per minute the curve branches into two, the upper branch corresponding to the resistance with dead water formed at the stern and the lower with this water detached. The lower curve is horizontal between 900 ft. per minute and 1,000 ft. per minute, as indicated by the table. It is not continued beyond the higher of these speeds, but the calculations for the Ramus ship which are based on this curve show that Mr. Froude has taken the resistance curve to be horizontal up to 1,250 ft. per minute. The upper branch is concave to the axis of speed between 600 ft. per minute and 800 ft. per minute, straight between 800 ft. per minute and 950 ft. per minute, but beyond the latter speed starts to rise rather rapidly. Thus the difference of the resistances at 800 ft. per minute and 1,000 ft. per minute is only ·1 lb., whilst between 1,000 ft. per minute and 1,200 ft. per minute, it is ·15 lb. It would appear that if the lower branch of the curve had been carried on beyond 1,000 ft. per minute it would also have shown the same relative rise at high speeds as the upper branch. The cause of this rapid increase is not clear.

In another set of experiments the centre of gravity of the smaller model was shifted forward by adjustment of weights. This brought the surfaces of the inclined planes almost parallel to the waterline when at rest. In this condition the model dived for all speeds below 500 ft. per minute. For higher speeds the bow rose and the stern sank, but the total resistance was increased. The increases at 600 ft. per minute, 800 ft. per minute and 1,000 ft. per minute were respectively 10 per cent., 17 per cent., and 28 per cent. of the resistances given by the lower branch of the curve of the original model.

One reason for the use of the two models was to test the law of similitude. Mr. Froude states that "the results fully confirm my assurance that the scale of comparison between models and ships can be relied on." It is interesting therefore, to compare the results obtained for the residuary resistance the total minus skin friction, curves of which for both models are given. At 900 ft. per minute the residuary resistance for the larger model is 11·07 lb. compared with 12·23 lb., as deduced from the smaller a difference of over 10 per cent. ;

at 800 ft. per minute the difference is 14 per cent., at 700 ft. per minute, 13 per cent., and at 600 ft. per minute, 7 per cent. In all cases the results deduced from the smaller are greater than those given for the larger model. The reason for these differences would appear to lie in the fact that with such forms of models there is a relatively large amount of eddy resistance. This, according to our later information, does not follow the same law of comparison as wave-making, but a law similar to that for skin frictional resistance. This eddy-making cannot, however, be separated from the wave-making, the whole being taken as residuary resistance and assumed to vary in accordance with Froude's law of comparison. The effect is to exaggerate the resistance of the full-sized ship and to give results which are the more erroneous the smaller the model used. In the case of the 2,500 ton Ramus ship, if the results of the larger model had been taken for estimating the resistance, the results would have been 5 per cent. to 7 per cent. lower than those obtained from the smaller model results, but even then the effect would not have been entirely eliminated.

It is interesting to determine from Mr. Froude's results for the smaller model the effective horse-power required for a vessel of 4 tons displacement, which is approximately that of the smaller coastal motor boats and racing craft. The length of the boat would be 43 ft., breadth 7·04 ft., and draught, 9·84 in. At about 22½ knots this boat would require the same horse-power as a boat of the same dimensions and displacement, but of ordinary form. Above this speed she would require less power, and below more than the other. At a speed of 15·4 knots she would begin to rise bodily and at 33 knots the rise would be about 7 in. The resistance becomes practically constant at 28 knots, but at 35 knots begins to increase appreciably.

The material of construction of the models is not stated by Mr. Froude, but if these are supposed of wood and varnished, the effective horse-power of the boat to obtain 30 knots would be about 160, or 40 per ton of displacement, which, for reasons referred to in the foregoing, would probably be reduced to 150 in the actual boat. At 35 knots corresponding to 1,000 ft. per minute in the model, the effective horse-power required would be 188, or only 28 additional for an increase of 5 knots speed. If the models used were of paraffin wax the effective horse-power for the 43 ft. boat at 30 knots would be about 200. Taking the larger model results as a basis, 18½ knots in the boat corresponds to 900 ft. per minute of the model and the effective horse-power required for this speed is 81 compared with 87, as deduced from the smaller model.

The foregoing figures are based on the results obtained from a model which was a most primitive example of the Ramus principle and in which no attempt was made to modify it with the view of decreasing the resistance. Utilising the original form as a basis designers have considerably modified and improved on it with the result that the resistance has been decreased to about 75 per cent. of that of the original. In this country Messrs. Thornycroft have been the pioneers in this work. The coastal motor boats designed and built by them for the Navy and which performed useful work during the later stages of the war are outstanding examples. These craft are fitted with engines of a power varying from about 60 to 80 brake horse-power per ton of displacement. Racing boats on the same principle have a much greater brake horse-power per ton, some of the latest having nearly 450 brake horse-power per ton, and attaining extraordinary high speeds.

Mr. Froude at the end of the second portion of his report gives a mathematical investigation of the problem involved. He assumed the normal pressure on the front of an inclined plane to be given by $P = 3\,AV^2 \sin\theta$, P being in lbs., A in square feet, V in knots, and θ the angle of inclination to the horizontal. The skin friction he assumed to be given by $F = \frac{1}{160} A\,(Vel)^2$, the velocity in this expression being that of the water along the plane and thus equal to the resolved part of the speed of plane along the latter, *i.e.*, $V \cos\theta$ where V = speed of model.

He assumed the whole weight of the model to be supported by the hydro-dynamical pressure and hence

$$W = P\cos\theta = 3\,AV^2 \sin\theta \cdot \cos\theta = 3\,AV^2 \cdot \theta$$

when θ is small. The resistance to motion is the sum of the horizontal resolved parts of P and F or

$$R = P\sin\theta + F\cos\theta = W\left[\theta + \frac{1}{300\,\theta}\right]$$

R is a minimum when $\theta = \frac{1}{17}$ or about 3½ deg., and is then equal to $\frac{2\,W}{17}$. At this minimum value of R the components of the resistance due to pressure and skin friction are equal. If θ is decreased beyond the angle stated, the component of the resistance due to pressure is decreased, but that due to skin friction is more than proportionally increased, so that the total resistance is greater. If θ is increased beyond $\frac{1}{17}$ the component due to pressure is increased, and that due to skin friction decreased, but not to the same extent.

The general result of the investigation was confirmed by constructing a model in which three separate models each with one inclined surface were used. The three were connected to a triangular framework, one model at the apex or forward end, being twice the width of the other two, which were at the extremities of the base, the length of base and height of triangle being so arranged that there was no interference in the wave systems and also no change of trim as speed increased. The inclined surfaces were not planes, but were curved with varying inclination, the slope decreasing from top to bottom. In one experiment the terminal slope was made 1 in 15. At 14 knots the model ran with not more than ½ in. immersed. This speed corresponded to 190 knots in the 2,500-ton ship. In a second experiment the terminal slope was made 1 in 50—the resistance component due to P was decreased—but at 14 knots the resistance was 15 per cent., greater than in the first experiment and the lift was sensibly less.

The mathematical investigation is necessarily an approximate one, but it is useful to compare the slope for minimum resistance with that of the Ramus models tried in the main experiments. θ, being the slope of the plane to the horizontal when the model is in motion, is the sum of the slope at rest and the angle of trim and this at 944 ft. per minute for the smaller model was about 5¾ deg. against the 3½ deg. of the investigation.

The remainder of the Parliamentary Return consists of some further letters from the Rev. Mr. Ramus, in which he criticized some of Mr. Froude's conclusions and the application of the law of comparison to resistances such as those experienced by models of this form. He also suggested, with a view to decreasing resistance, that the comparative breadth should be increased, the forward plane should be made longer than the after one and also that the stern of the model and the after end of after plane should be altered to prevent the dragging of deadwater. He also objected to the publication of an article in the Annual of the School of Naval Architecture which contained the mathematical investigation and the experiments confirming this referred to above, but which omitted his name. The article was, however, published and the whole matter terminated.

The Reverend Mr. Ramus, 12 months afterwards, suggested to the Admiralty that vessels of about 50 tons to 100 tons, with bottoms formed of three inclined stepped planes and propelled by rockets, which he considered would give them a speed of 200 knots to 300 knots, should be used for attack of enemy ships by being discharged against them. This letter was referred to Mr. Froude, who very effectively reported against this suggestion. This report is interesting, since in it Mr. Froude states that in former years he had been a most successful rocket maker—"having made hundreds of all sizes, some unusually large, and always very superior to those ordinarily sold," and gives formulæ for the propulsive force and time of forcible combustion in terms of the weight and diameter of the rocket. This report was printed as a Parliamentary Return called for in 1874 by Mr. (afterwards Sir Edward) Reed, who had been elected to Parliament in that year.

Although many boats embodying the Ramus principle have been built and have attained remarkably high speeds, very little information on the matter has been published. In 1909 Sir John Thornycroft read a paper before the British Association, in which he gave some photos of models and boats at high speeds. He also included a diagram showing the curves of resistance of a boat of Ramus form and another termed "Gyrinus." This diagram shows that equality of resistance occurs at 17 knots and that above this speed the Ramus form is considerably less resistful. The length of the forms is not given, but comparing the 17 knots with the 65 knots of the 370 ft. length ships of Ramus and Pro Ramus forms the length should be 25 feet. Mr. Sydney Barnaby, of Messrs. Thornycrofts, informs me the actual length of Gyrinus was 26 ft., and she was of ordinary form with no step.

Possibly now that the principle advocated nearly 50 years ago by the Reverend Mr. Ramus has been relatively so widely adopted, further information on this interesting subject will be forthcoming from those who have so successfully employed it in practice.

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*Continued from page* 372.)

IN our article this week we propose to deal with a number of the grinding machines on view at Olympia, and afterwards to deal with drilling machines and various other miscellaneous exhibits. In approaching the termination of our articles on the exhibition, it is becoming less possible to arrange the various tools in logical groups, as there are examples of machines with which we wish to deal which lack of space has prevented us from describing in conjunction with others of their class.

GRINDING MACHINERY.

We may begin our reference to some of the grinding machines at the show by dealing with the display made by Messrs. Charles Churchill & Co., Ltd., of 9 to 15, Leonard Street, Finsbury, London, E.C. 2. This firm exhibit various of the well-known and excellent machines made by the Churchill Machine Tool Company, Limited, of Broadheath, Manchester. A 12 in. by 60 in. plain grinder is shown. This takes an 18 in. by 3 in. wheel, and is arranged for two wheel speeds. There are eight work speeds and 12 table speeds. As in all Churchill machines the work and table speeds are entirely independent from each other, so that it is always possible to utilise to full advantage the full width of the grinding wheel by arranging the speeds so that the table travel equals nearly the full width of the wheel per revolution of work. The work table pivots on a hardened central stud, and can be set at an angle to the ways for taper grinding. Any angle up to 9 deg. is embraced. The wheel is supplied with a forged steel guard. In this connection we may say that in the course of considerable experience during the war with a battery of Churchill grinders, much of the type we are concerned with here, we had many cases of bursting wheels, but in every case the guard caught the flying parts successfully and no outside damage was done. As the machines were operated by girls a single accident might have seriously interfered with important output. It should, perhaps, be explained that the reason for bursting wheels was that, owing to shortage of standard supplies, wheels of any make and every make and no sort of make were pressed into service.

A Churchill vertical spindle surface-grinding machine is also on view. This has a working surface of table of 40 in. by 16½ in., and employs an 18-in. cup wheel. There are four change-speeds for the table, ranging from 3 ft. 9 in. to 15 ft. per minute. The wheel head is carried on square gibbed slides on an upright, and has automatic down feeds with trip motion which range from 0·000125 in. to 0·0015 in. at each stroke of the table. Fine hand feed is also provided, as well as quick hand motion. These are both controlled from the front of the machine, and an indicator is carried on the head which approximately shows the position of the grinding wheel in relation to the work. The spindle driving bracket with its driving pulley is a self-contained

unit. The driving pulley is carried on a sleeve running on ball bearings on either side, and the spindle slides freely through the sleeve, and is driven by double keys. With this construction no pull of the belt comes on the spindle, so that its movement remains quite sensitive. The wheel spindle is fitted with a ball thrust and is balanced to prevent drop, or lost motion. All motions are operated from the feed-control apron on the front of the table.

A very adequate display of grinding machines is made by Messrs. A. A. Jones and Shipman, Limited, of East Park Road, Leicester. This firm shows in all some dozen machines of various sizes and types, the examples including plain cylindrical, internal, and universal grinding machines, tool-grinders, &c. From among these various tools we illustrate, in Fig. 164, annexed, a 24-in. internal and external grinder. The machine is of full universal type, and all kinds of cylindrical work, external and internal and parallel or taper, can be dealt with by it. It has a capacity of 24 in. between centres, and can take work of 12 in. diameter. Change-over from internal to external grinding, or *vice versa*, is made by swivelling round the main grinder head. This brings either the external or internal wheels into use without disturbing the work. Holes from $\frac{5}{8}$ in. up to 5 in. diameter and $3\frac{1}{2}$ in. deep can be internally ground.

The automatic table traverse has eight variations of speed, ranging from 15 in. a minute up to 109 ft. a minute. The length of traverse is 24 in. The cross-slide on which the wheel head is mounted carries a top slide which may be set round to any angle, a scale reading to 90 deg. both ways being provided. The cross-feed is automatic and variable, the wheel being advanced into the work at from 0·0002 in. for each reversal of the table up to a maximum of 0·0016 in. Automatic sizing is obtained by setting an adjustable knock-out to the required diameter. This knock-out cuts off the automatic cross-feed when the wheel has advanced the pre-determined amount. The work-head is mounted on a circular base and may be set to any desired angle, a graduated scale being provided. The spindle also may be locked and the front pulley used as a driver for dead-centre work, or the pulleys may be removed and a chuck substituted. The tail-stock is lever-operated, and the compression of the spring is so arranged that it may be adjusted for light and heavy work. It can also be set for any given position, thus preventing the centre from pressing into the work more than the desired amount. The wheel head has a vertical adjustment of 7 in. on its column, and is operated by a screw and hand-wheel. The graduations on the hand-wheel read to 0·0005 in. Wheels may be carried at either end of the external grinding spindle. The head can be locked in any position.

Two Norton machines which are shown for the first time in this country are exhibited at one of the stands of Messrs. Alfred Herbert, Limited, who are agents for the Norton Company of Worcester, Mass., U.S.A. One of these is illustrated in Fig. 165, annexed, and Figs. 166 and 167, Plate L, with our issue this week. This is a 10 in. by 72 in. cylindrical grinder, driven by a 15 h.p. electric motor, running at a speed of 1,200 r.p.m. The largest wheel taken is 24 in. by 6 in. There are only two belts in the machine and they are totally enclosed. They are provided with adjustable idlers running on ball bearings automatically oiled. The machine is fitted throughout with ball bearings which number no less than 47, all enclosed in oil baths.

The table traverse speeds are seven in number, the truing speed being 2·9 ft. per minute and the regular speeds ranging from 10 ft. to 32 ft. per minute. The truing speed can be thrown in carelessly, or what other speed is in gear at the time, by a single lever movement. The table traverse is started and stopped simultaneously with the revolution of the work, or the work can be started and stopped alone. The headstock drive is by spiral worm wheel, enclosed in an oil bath. The number of work speeds is six, ranging from 53 to 160 r.p.m. The wheel slide has bearing ways 20½ in. long. The slide carries a chain-driven pump and oil reservoir for oiling the wheel spindle bearings. The wheel spindle is driven by belt from a shaft enclosed in the base. The length of the wheel spindle is $37\frac{1}{2}$ in.; it is carried in bearings $8\frac{3}{8}$ in. and 7 in. long. The spindle pulley is 9 in. in diameter and the spindle speed 1,300 r.p.m.

Fig. 164. Internal and External Grinding Machine; Messrs. A. A. Jones and Shipman, Ltd.

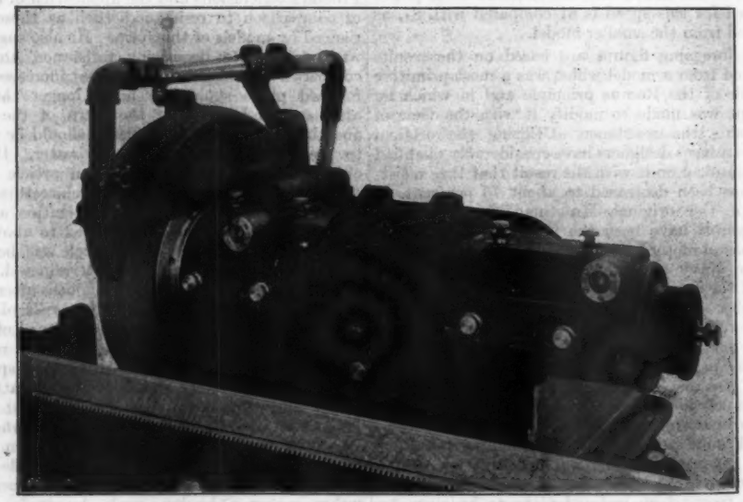


Fig. 165. Details of Wheel Head of Norton Cylindrical Grinder.

adjustment of the bearings can be made by thumb screw while the machine is running. The wheel has quick acting hand cross traverse with micrometer adjustment. The automatic feed is by pawl, and takes effect either at the end of or during each table stroke, whichever is selected. The pump tank is arranged on wheels so that it is in the form of a hand cart. The pump is arranged to swing out of the tank when the latter is removed for renewing the compound. Fig. 165 shows a detail of the grinding wheel head.

The Norton 12 in. by 36 in. Universal grinder is another excellent example of this well known make of machines. This is illustrated in Figs. 168 and 169 Plate L. The base has three feet, two in front and one directly under the wheel head, behind. The drive is by single pulley completely enclosed in a guard which may be set to any belt angle. The headstock is arranged to swivel, with a setting index

graduated in degrees. The headstock drive, as will be seen in our illustrations, is through splined shaft, and bevels carried in a bracket. There are six work speeds. These range from 53 to 320 r.p.m. The gears are contained in the headstock, and these changes are independent of the table or wheel speeds. The headstock spindle is hollow and will pass ¾ in. rods. The drive plate or chuck is driven from the gear-box by Morse chain and the spindle pulley is split and can be changed for another size when required. The spindle is driven by belt, over idler pulleys; an automatic belt tightener keeps a constant tension on the belt. The wheel feed is automatic or by hand, the former ranging from ·0025 in. to ·004 in. through 16 steps, and takes effect at the end of the table stroke. An automatic adjustable feed stop may be set to stop the feed on the required size being attained. The

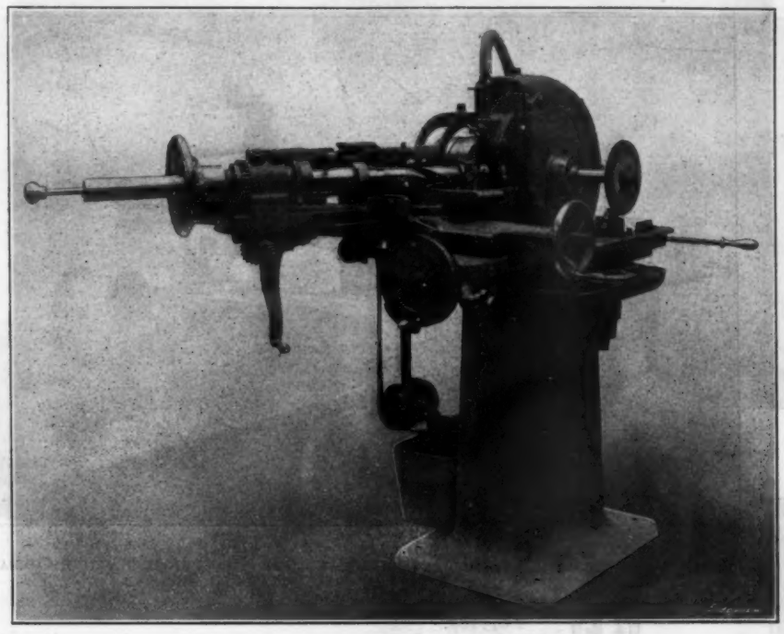


FIG. 174.

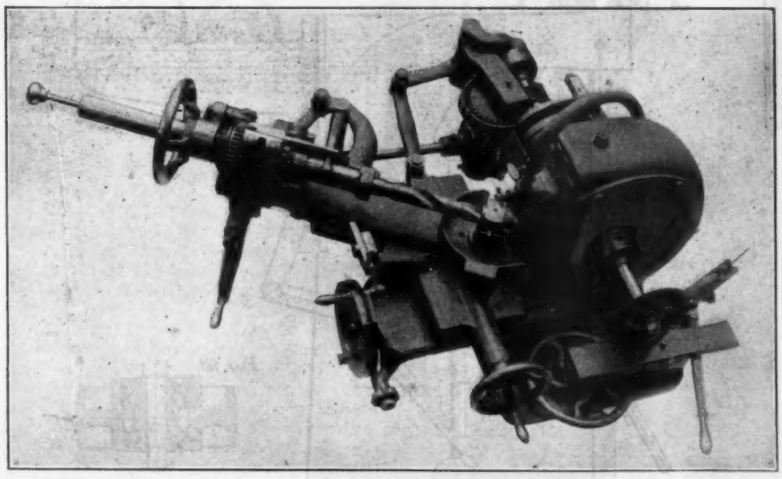


FIG. 175.

FIGS. 174 TO 176. TWIST-DRILL POINT-SHARPENING AND THINNING MACHINE; MESSRS. HERBERT HUNT AND SONS.

centre can either revolve, or remain dead for plain cylindrical grinding. The tail stock has a diamond tool holder fitted to the centre.

The wheel head swivels on its base through 180 deg. It has a graduated base. The cross-slide may also be rotated through any angle to a position parallel with the work. The head is arranged for an internal grinding spindle at one end, and for the ordinary disc wheels at the other, either being swivelled into position as required. The wheel spindle is arranged for two wheels, one on either side of the bearings and central pulley. The wheels are 12 in. in diameter by $\frac{1}{8}$ in. to $\frac{3}{4}$ in. thick. The table speeds are eight, ranging from 2 ft. to 11¼ ft. per minute, obtained by means of a four-step cone pulley and back gears. The upper part of the table is made to swivel and a triple scale at one end gives readings up to 7 deg. or 5 deg. tapers up to 3 in. per foot, or percentages up to 25 per cent. The equipment includes a spindle for internal work, and steady rests, etc.

In Figs. 170 to 173, on Plate LI, we illustrate the ball-bearing twist-drill grinder manufactured and shown by Messrs. Alfred Herbert, Limited, of Coventry. Machines of this type have been made by Messrs. Herbert for some years, and the detail of particular interest in the machine exhibited, and which we illustrate, is the new point thinning attachment which has recently been added. The machine has a 9½-in. wheel carried on a spindle running in water-tight single-track ball bearings, end play being automatically taken up by a spring. Cooling water is contained in the casing which forms a guard for the wheel, and the wheel itself acts as its own pump. A wheel-truing arrangement is

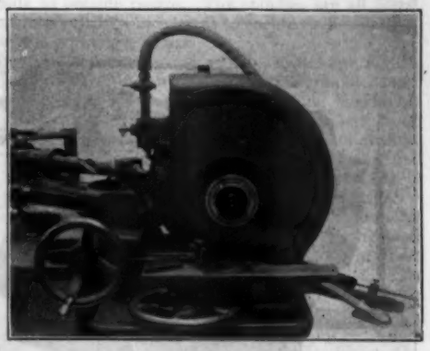


FIG. 176.

fitted, which can be used at any time without disturbing the adjustment of the machine. The drill-holder oscillates on dust-proof ball bearings, and as it is not adjustable to and from the wheel, it remains at all times very stiff. Two liners for the vee holders are provided for grinding drills with alternative amounts of clearance, and a small vee holder is supplied for grinding very small drills.

The point-thinning attachment consists of a vee holder in which the drill is placed, the holder being provided with an adjustable swivel carried on a working slide which is balanced by a spring. The vee holder contains an adjustable finger which engages with the edge of the drill flute and enables the drill to be set in the correct position circumferentially. To use the device the drill is placed in the holder, and one cutting lip is set parallel to the plane of the wheel by means of the finger and the swivel. The cut is regulated by a transverse adjustment, and by an adjustment radial to the wheel. The drill is then moved tangentially across the wheel by hand. After grinding one edge, the drill is turned over so that the finger engages the other flute for grinding the second edge. A centrifugal pump and water-guards are provided to enable the drills to be ground wet. This device grinds each edge of the drill symmetrically about the centre independently of the depth of the flutes. If, as is not infrequently the case, one groove in a twist drill is deeper than the others, thinning uniformly about the apparent centre, as one would naturally do if grinding by hand, will cause the drill to cut big. The point-thinning attachment prevents this, and also prevents the point being thinned with a negative rake.

A machine for twist-drill point sharpening and thinning is also exhibited by Messrs. Herbert Hunt & Sons, of Elsinore Road, Old Trafford, Manchester. It is shown on the stand of Messrs. W. A. Walber & Co., of 38, Victoria Street, London, S.W. 1. The machine is illustrated in Figs. 174 to 176, annexed. One of its special features is that it is automatic and can be set to grind any quantity of drills to the same length. This is of great value in connection with multiple drilling machines. The tool is, however, equally suitable for dealing with a single drill. A hand-operated type of machine is also made, but as our illustrations show the automatic machine, we will confine our description to that. The operation of the machine depends, briefly, upon the revolving of the drill continuously in one direction, while supported in a bush, and imparting the necessary motions to give the correct clearance to the lips. The drill is fed forward a pre-determined amount once during each complete revolution.

The operation of the automatic mechanism will be best followed from Fig. 175. The drill to be

ground is chucked in an ordinary socket and is secured by a quarter turn of a milled nut, and the various automatic motions are driven from the grinding-head spindle. A worm and worm-wheel and bevel gears drive from the main spindle and give motion to a vertical spindle mounted on the slide which carries the drill. This shaft is behind the slide in Fig. 175, and cannot be seen. A crank disc is mounted on the end of this vertical shaft, and the pin is coupled by a connecting-rod to the fixed frame of the machine. The result of this is that the rotation of the vertical shaft causes the swivel slide to oscillate around its pivot, which is placed near the grinding wheel, as can be seen in the figure. In addition to this swivelling motion, a reciprocating motion is introduced which causes the spindle carrying the drill to advance to and retire from the grinding wheel. This motion comes from the small horizontal shaft which can be seen behind the drill spindle in the figure. This shaft is driven from the vertical shaft by bevel gears, and drives the drill spindle through the spur gearing which can be seen. This gearing causes the drill spindle to rotate once for every two revolutions of the short horizontal shaft. The to and fro reciprocation of the drill spindle is obtained from a cam and a yoke on the short horizontal shaft, and the effect of the 2 to 1 gear is that the to and fro motion is repeated for each lip of the drill. An automatic feed, which can be varied from 0·001 in. to 0·015 in. per revolution, of the drill is provided in connection with the cross-slide on which the pivot slide is fitted. It is ratchet-driven, and can be seen in Figs. 174 and 175. A point thinning attachment is fitted to the machine, and is shown in Fig. 176. It carries the drill at the correct angle to the grinding wheel, and is provided with a stop which supports the end of the drill and a finger which engages the cutting lip. The necessary motion is given by a lever operating the slide which passes the drill beneath the grinding wheel.

A grinder for dealing with curved-lip tools is illustrated in Figs. 177 and 178, subjoined. It is manufactured by the Lumsden Machine Company, Ltd., of Gateshead, and is exhibited by Messrs. Alfred Herbert, Ltd., their agents. The machine, as will be seen, is of the double-ended type. One end carries the cup-wheel and holder for grinding curved-lip tools, and the other a cup-wheel and tool-rest, and is intended for re-touching the flat faces of ground tools after hardening. The main spindle is carried in ball bearings, and is fitted with ball-thrust bushes. The self-contained countershaft also runs in ball bearings. A centrifugal pump, feeding both grinding wheels, is driven by a belt from the countershaft. The curved-lip mechanism consists of a horizontal traversing slide mounted on a column having vertical adjustment. The slide is pivoted on the column, and can be swung round and secured at any angle in the horizontal plane of the wheel. The slide carries a cross-slide which, in turn, carries a swivelling vice, the base of which is at about 40 deg. to the slide. A cast-iron trough protects the operator from water and dust, and all controls are from outside. With a tool in place in the vice, the operation of grinding consists in first swivelling the vice until the cutting edge of the tool is parallel to the bottom traverse slide. The traverse slide is then moved round to the desired angle for giving the required top rake, and the whole arrangement is lifted by the elevating control until the tool touches the periphery of the grinding wheel. The tool is then reciprocated across the wheel, and at the same time fed upwards by the elevating control until the required depth of cutting clearances is obtained.

An interesting little appliance, also shown by Messrs. Alfred Herbert, is illustrated in Fig. 179,

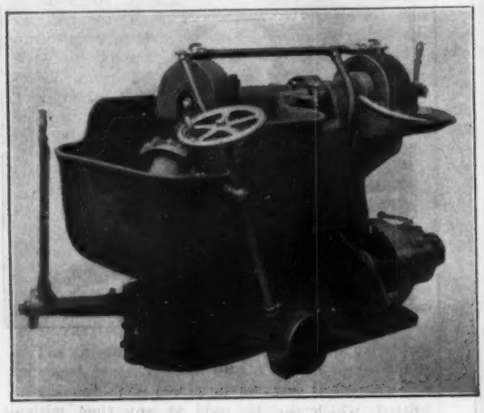


FIG. 177.

FIG. 178.

FIGS. 177 AND 178. CURVED LIP TOOL-GRINDER; MESSRS. THE LUMSDEN MACHINE COMPANY, LTD.

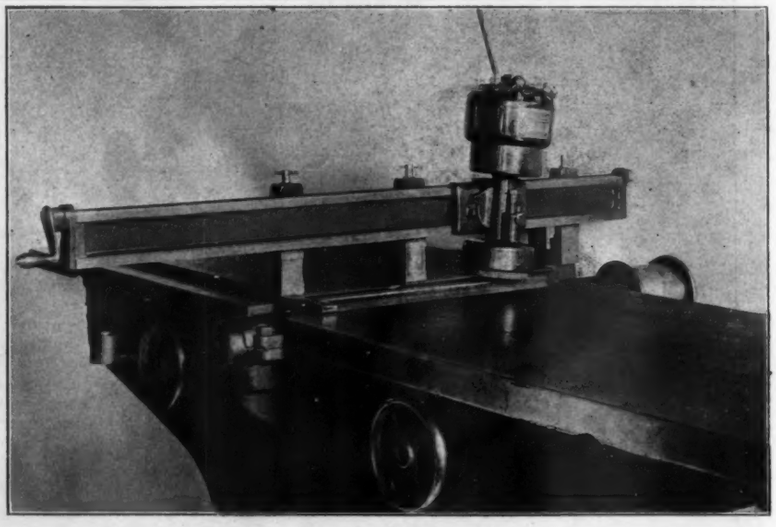
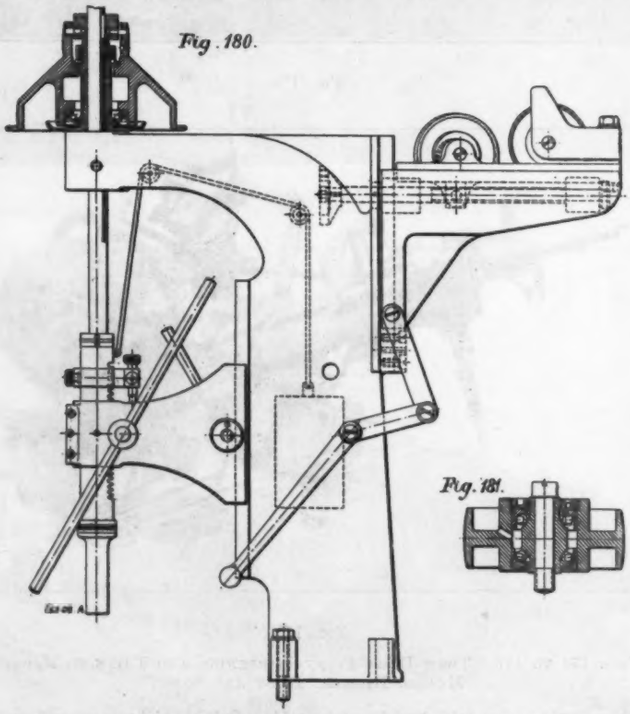


FIG. 179. QUICSHARP KNIFE-SHARPENER; MESSRS. THE STOCKBRIDGE MACHINE COMPANY.



FIGS. 180 AND 181. HIGH-SPEED SENSITIVE DRILL; MESSRS. B.S.A. TOOLS, LTD.

on page 400. It is known as the "Quicsharp" knife-grinder, and is intended, in the main, for sharpening the blades of wood-planing machines. Its features will almost be evident from the illustration. It is a self-contained arrangement, consisting of a 4-in. cup grinding wheel carried at the bottom of a vertical spindle which is motor-driven from the top. This arrangement is carried on a bracket, and may be tilted, while the bracket is mounted on a horizontal guide along which it is traversed by hand by means of a lead screw. The appliance may easily be attached to a wood planer, and will, with a few minutes' work a day, keep the knives keen and dead true.

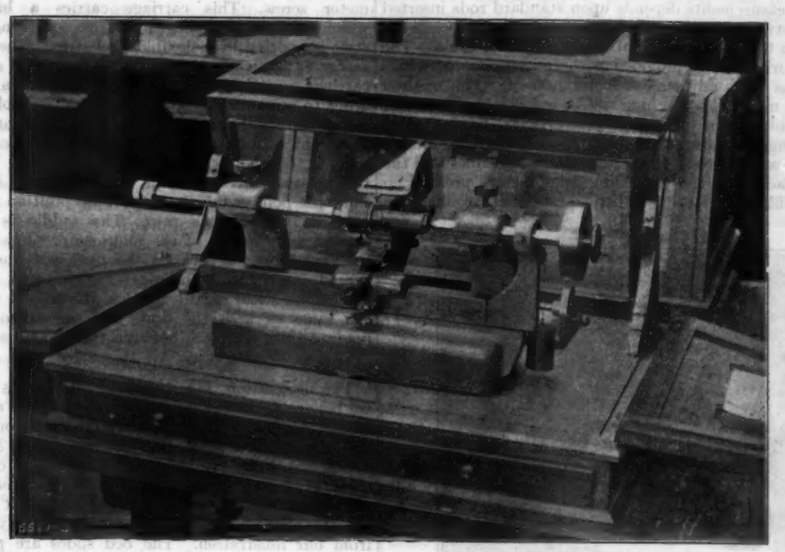


FIG. 192. PITCH MEASURING MACHINE; THE TECHNICAL COLLEGE, LOUGHBOROUGH.

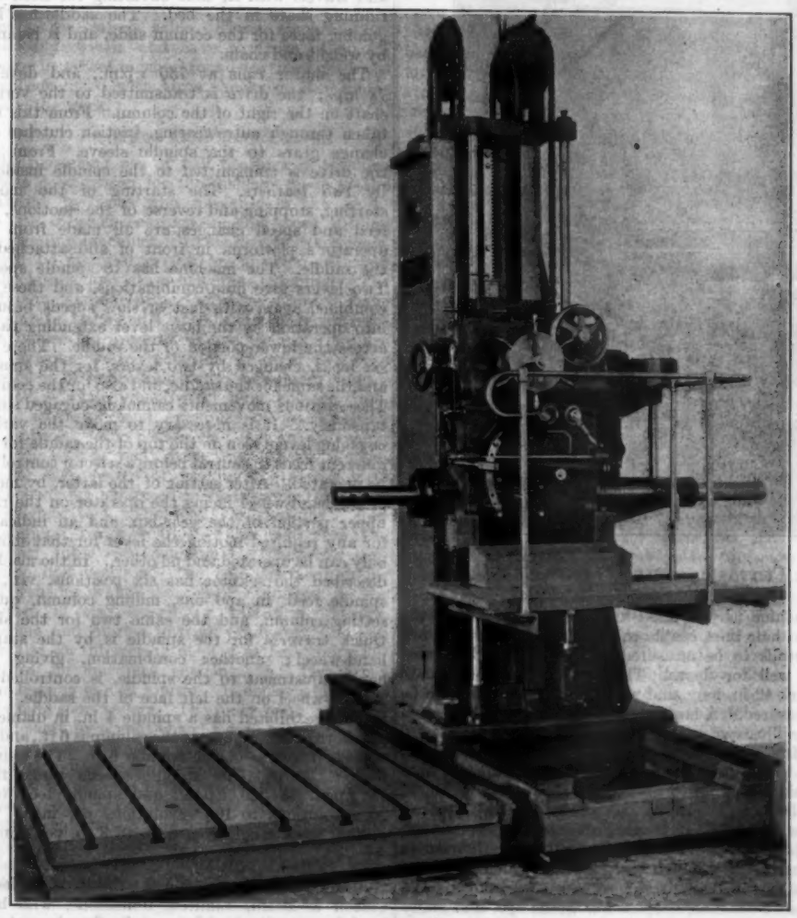


FIG. 193. HORIZONTAL BORING MACHINE; MESSRS. THOS. SHANKS AND CO.

A good many other firms exhibit grinding machinery of one kind and another, with which, however, it is only possible for us to deal comparatively briefly. Messrs. A. Harper, Sons & Bean, Ltd., Dudley, have a number of excellently finished floor and disc grinders, the chief interest in which centres in their bearings, lubrication, &c. Lubricating rings are fitted and ball journal and thrust bearings where required. The firm also show a valve-grinding machine for petrol engines. This has eight adjustable oscillating spindles which can be set from 2 in. centres up to 23 in. from outside to outside centre. The spindles are all lifted at intervals by a cam, so as to ensure re-distribution of the grinding medium.

Messrs. Honeywill Brothers, 79, Mark Lane, E.C. 3, have a large assortment of knife-grinders, and also exhibit automatic saw-sharpening machines. Their "universal" sharpener for circular, band and frame saws has full automatic movements. This machine is capable of gulletting, topping and bevelling in one operation. It is fitted with a ball-bearing head. Another interesting saw-sharpener is shown by Messrs. A. Ransome & Co., Ltd., Newark, for band saws from 2½ in. to 8 in. wide; this machine performs the operation of gulletting, backing and facing at each stroke of the grinder carriage. The firm also show automatic machines for circular saws up to 7 ft. in diameter, and a small machine capable of dealing with circular saws up to 24 in., or the narrow band saws up to 25 ft. in length. Messrs. Isaac Hill & Son, Derby, one of whose cold-sawing machines we noticed last week, are also showing an automatic cold saw-sharpening machine for saws up to 36 in. diameter.

DRILLING MACHINES.

A new drill termed the B.S.A. high speed sensitive drill is illustrated in Figs. 182 to 184 Plate LII, details being given to a somewhat larger scale in Figs. 180 and 181, page 400. This drill is shown at the stand of Messrs. Burton, Griffiths & Co., Limited. The drill has six speeds all obtained by belts. The main drive is by single speed belt pulley on a small countershaft on the back of the machine. On this shaft is a three-step cone pulley, driving by belts a corresponding pulley about half way up the column. From a pulley on the shaft on which the second cone is mounted, a belt is carried over jockeys to a two step cone pulley driving the spindle direct. The belt is shifted on the three step pulleys by lever and fork. To obtain the six speeds either of these sets of steps is combined with one or other of the two to the spindle. The jockeys are mounted in a slide which can be traversed away from the spindle, by screw for belt tightening. The slide is mounted on a bracket sliding on the column, its position being controlled by a lever and coupling links. When using the small step of the spindle pulley the bracket carrying the jockeys is raised to the position shown in dotted lines in Fig. 180, thus taking up the belt slack, and tracking the pulleys automatically.

It will be noticed that ball bearings are fitted throughout the machine, which will take the largest size drill which will fit the No. 2 Morse taper. The top cone pulley is mounted on a sleeve and the drive is transmitted through a floating bush. The spindle runs in this sleeve and in a second in the sliding head. It is fitted with ball thrust bearings. A stop is fitted on the sleeve which meshes with the rack, and also has fine vertical adjustment by screw. The sliding head can be clamped. The table also can be clamped. The latter is fitted with trough edges. It is raised and lowered by rack and pinion in the machine shown, and also in the two-spindle machine. In three and four spindle models tables are raised and lowered by telescopic screw.

A very notable high-power drilling and tapping machine is shown by Messrs. A. A. Jones & Shipman, Limited, of Leicester, in their No. 484 model 30-in. upright drill. This is illustrated in Figs. 185 and 186, Plate LII, at work on mild steel gear blanks 4 in. deep. The time for drilling a 3-in. hole through these is two minutes, in ordinary work. We are informed that this machine will drill 2-in. holes 8½ in. deep in shell steel in two minutes. The machine stands about 10 ft. 6 in. high. It is driven by four-step cone pulley at the base of the column with corresponding cone at the back of the head. The latter drives the spindle through bevel

gearing giving 3:1 reduction. The end thrust of the bevels is taken on ball bearings. These gears run in an oil bath at the head of the column. Back gears are provided so that a range of eight spindle speeds is possible, from 24 to 200 r.p.m. The feeds are nine in number, ranging from 1-in. feed per 31 revolutions of the spindle, to 1 in. per 302 revolutions. Any can be used with any spindle speed. They are changed by hand-wheels on the end of the gear-box shown in Fig. 186. The feed-drive is conveyed from the head of the machine to the gear-box by a small vertical shaft driven by roller chain from the drill spindle. The spindle is fitted with top and bottom ball-thrust bearings for drilling, tapping and withdrawal. The quick hand-feed is by large hand levers, and the fine hand-feed by the hand-wheel in front of the drilling head.

A ¼-in. shearing-pin is arranged in the feed worm-wheel. The cross-axle for the feed is provided with an outside bracket bearing. An automatic trip for depth drilling is provided with an adjustable stop and graduated stop-bar. A knock-out prevents over-running. The maximum feed of the spindle is 18 in. The table has a vertical adjustment of 18 in. The machine can be fitted with a swing-table, which can be pushed to one side clear of the base.

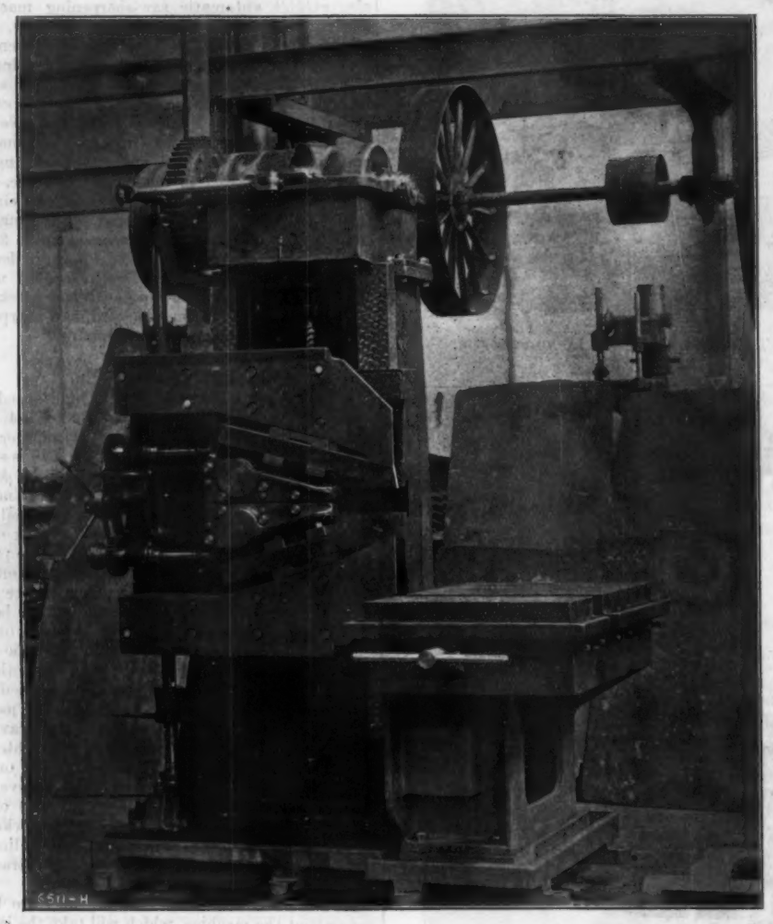


FIG. 194. GIT SLOTTER; MESSRS. CLIFTON AND BAIRD, LTD.

MEASURING MACHINES.

A simple measuring machine of an accuracy sufficient for all ordinary shop purposes is illustrated in Fig. 187, Plate LIII. This is produced by Messrs. Alfred Herbert, Limited, Coventry, and consists of a bed with a sliding work table and a microscope mounted on a compound slide. The latter is furnished with large dial micrometers reading to ·0001 in. In addition, the microscope is fitted with two hair lines, one rotating with the eye piece, and one with the outside tube. This is fitted with a large dial reading to half degrees, while the eye piece carries a vernier reading to one minute. The accuracy of measurements depends upon standard rods inserted between blocks at the left hand end, one block being on the bed, and the other on the work table. The work table is provided with centres, one of which has cross adjustment for alignment. The method of use of this machine will be evident in the case of limit gauges and such like articles having plain length measurements for the selection of suitable measuring rods, the setting of the hair lines and the reading of the traversing micrometers present no difficulties. With a little additional trouble the machine may be used for contour work, while the two hair lines enable the pitch and angle of screw threads to be measured and threads to be tested as well for depth. The table will accommodate work 12 in. long, and work 3 in. in diameter can be measured. A lamp and mirror are set as shown in our illustration to give clear projection.

In Figs. 188 to 191, on Plate LIII, and in Fig. 192, on page 401, we show a pitch-measuring machine which is exhibited by the Loughborough Technical College. The apparatus, which was designed at the National Physical Laboratory, is of much interest in itself, but carries a further interest as illustrating the high class of work which is turned out in the Loughborough College workshops. We dealt with these shops a few weeks ago, and many visitors to Olympia will probably be glad of the opportunity of seeing something of the class of work which is being turned out by the students and trainers. The exhibition stall also contains a number of machine vices made at Loughborough which would be a credit to any factory.

The pitch-measuring machine consists of a main bed carrying centres between which screw-gauges may be supported. A carriage running between them is carried on six balls, and is capable of being traversed a distance of 1 in. by means of a micrometer screw. This carriage carries a bracket which supports an indicating device consisting of a stylo supported by a flexible steel strip. The stylo serves as a means of locating the position of the carriage in relation to the screw-thread; and in order to measure the pitch, a stylo of suitable size is selected so that when brought forward into engagement with the flanks of a thread it makes contact at, or about, the effective diameter. When the pressure on each flank of the thread is the same the pointer takes up a definite position which may be regarded as zero. The saddle is then traversed by means of the micrometer screw until the stylo engages between the flanks of the next thread, and the pointer returns to zero. The conditions with regard to this thread are then the same as with the first, and the micrometer reading gives the pitch between the two threads.

BORING MACHINE.

The illustration, Fig. 193, page 401, shows what we believe to be the largest boring machine at the exhibition, though a comparatively small one for its makers. It is by Messrs. Thomas Shanks & Co., Johnstone, who have long made a speciality of this class of machine. It embodies several features which are innovations in their designs. It is of the traversing-column type, as will be easily seen from our illustration. The bed slides are placed far apart. The horizontal traverse is by rack. The driving motor is fixed to the base of the column, and travels with it, thus obviating the need of a running shaft in the bed. The saddle has long guiding faces for the column slide, and is balanced by weight and chain.

The motor runs at 750 r.p.m., and develops 7½ h.p.; the drive is transmitted to the vertical shaft on the right of the column. From this it is taken through mitre-gearing, friction clutches and change gears to the spindle sleeve. From this the drive is transmitted to the spindle inside it, by two feathers. The starting of the motor, starting, stopping and reverse of the motions, the feed and speed changes, are all made from the operator's platform, in front of and attached to the saddle. The machine has 18 spindle speeds. Two levers give nine combinations, and these are combined again with fast or slow speeds brought into operation by the large lever extending partly across the lower portion of the saddle. There are six feeds, changed by two levers, for the spindle, and the same for the saddle, and also for the column. These various movements cannot be engaged simultaneously. It is necessary to move the various engaging levers seen on the top of the saddle for the different feeds to neutral before a selector control can be operated. After setting of the latter, by means of the hand-wheel facing the operator on the right upper portion of the gear-box and an indicator, for any required motion the lever for that motion only can be operated and no other. In the machine described the selector has six positions, viz., for spindle feed, in and out, milling column, quick-setting column, and the same two for the slide. Quick traverse for the spindle is by the starred hand-wheel; another combination, giving fine hand adjustment to the spindle, is controlled by a hand-wheel on the left face of the saddle. The machine exhibited has a spindle 4 in. in diameter. The horizontal traverse of the column is 6 ft., and the vertical traverse of the spindle 6 ft. The spindle feed is 30 in. The spindle speeds range from 14 r.p.m. to 300 r.p.m., and spindle feed from 20 revolutions to 100 revolutions per inch. The milling feeds range from 6 in. to 3 in. per minute.

GIT SLOTTER.

A new form of git slotter is exhibited by Messrs. Clifton & Baird, Limited, Johnstone, who have brought out this machine to take the place of cold sawing for cutting off gates and risers of castings. The machine shown is one of the smaller sizes made, but the output even in this case is far beyond what is possible with a cold saw. The machine is illustrated in Fig. 194, annexed. It is belt-driven, and consists of a column providing slides for a tool saddle, which is worked up and down

by a vertical quick-pitch reversing screw. A table is provided on one side of the column, and this is slotted in order to allow the tools on the slide to be fed forward through the work. The saddle carries two tools which cut on alternate up and down strokes; one tool is pointed and the other square tipped. They are carried in pivotted tool-boxes to provide relief for the non-cutting stroke, and are returned to the cutting position by springs. The tools are supported by very deep and stiff backing-plates fixed to the saddle. The two tools can be fed in independently or together, either by hand, or automatically. In the latter case on the downward travel a hook hanging from a lever on the feed spur spindle engages with a lip on a block on a vertical rod. Towards the end of this stroke a finger on the saddle comes in contact with a cam on this block and causes the rod to rotate partially. This has the effect of throwing over a reversing dog-clutch in the gear-box at the head of the column. The saddle then commences to travel upwards, and the hook being engaged with the block, the feed spur is pulled round by a pawl on the lever above referred to. As the saddle rises further the hook is forced out and disengaged automatically. At the top of the travel is another cam-block for reversing only. The feed can be regulated by a trip-plate set under the pawl. The pawl movement is always the same, but this plate can be set so that the pawl engages one or more teeth as required. The feed only takes place at the bottom end of the stroke. The saddle is balanced by chain and weight. The stroke on the machine shown is 18 in., and the feed or depth of cut, a maximum of 8 in. This machine will cut off a riser 15½ in. by 6 in. in 18½ minutes. Larger machines have a plain base without the raised table. These machines are electrically driven, and have a stroke of 30 in. In some instances in wheel foundries these machines have been fitted with large chucks or face plates to take the work.

Ball Bearings and Chain Drives.

The increasing use of ball bearings in machine tools is good reason for the displays made at the exhibition by firms who specialise in this work. The use of such bearings in high-speed drilling and grinding machines is extending to other tools, as will be manifest on an examination of many of the lathes, and other machines exhibited. The Hoffmann Manufacturing Company, Limited, have on exhibit a lathe and a lathe headstock which have been in use for upwards of five years. They are also showing worm reduction gears of the type adopted by Messrs. David Brown and Sons (Hudd.), Limited, a waste breaking machine, colliery tram, cream separator, and examples of line shafting also so fitted. The Skefko Ball Bearing Company, Limited, has a very attractive exhibit demonstrating the process of gauging for accuracy to which balls are subjected in their works, including a resiliency test. The firm are showing a new self-aligning roller bearing which embodies the spherical outer race common to the firm's self-aligning ball bearings. The ball bearing hub for road vehicles which we recently noticed in our columns, is also shown by this firm. Messrs. Ransome and Marles Bearing Company, Limited, have also an interesting display of ball and roller bearings, for machines, shafting, &c. This firm's roller bearing is well known. It consists of a cage containing short rollers. The inner track is secured to the shaft by a split-coned sleeve and nut. The outer track is ground spherical on the outside and oscillates in the plummer block. The double-row ball bearing consists of two rows of balls running on separate tracks ground to radii conforming closely to the balls. The outside of the track ring is again ground spherical.

The Coventry Chain Company, Limited, have exhibited a combination of drives which include their inverted tooth type of chain, their double roller chain and chain triple-reduction speed box. The first is suitable for high-speeds and powers, the second, of course, for lower speeds, while the latter are arranged for both high and low powers and ratios. Messrs. Brampton Brothers, Limited, Oliver-street Works, Birmingham, also show their inverted tooth chains, and also roller and compound roller driving chains. The former type is suitable for high-speed and power transmission, the latter being more particularly for drives at slow speeds. Engineers are now so familiar with the application of chain drives that it is unnecessary to say more about these particular exhibits.

(To be continued.)

THE INSTITUTE OF METALS.

In our issue of last week (*vide* page 381 *ante*) we gave an account of the opening proceedings at the meeting of the Institute of Metals, held at Barrow-in-Furness on the 15th and 16th inst., and we have now to deal with the papers read and discussed.

Notes on Brass Foundry Practice.

The first paper taken at the meeting on the morning of Wednesday the 15th inst. was entitled "Notes on Brass Foundry Practice at Messrs. Vickers, Limited, Barrow," by Mr. H. B. Weeks, F.I.C., who read it in abstract. This paper we reproduced in full on page 389 *ante*. Mr. Weeks emphasised the great assistance which manufacturers had received from the papers which had been presented to the Institute since its foundation and from the discussions that had taken place thereon. His own paper, he added, was to give a practical touch to others which were on the programme of the meetings then being held. At the present moment there was not a very large demand for non-ferrous castings, the demand being specially for iron castings.

Sir George Goodwin stated that the paper would serve as a guide to the members when they visited Messrs. Vickers' works in the afternoon, and it had been written at his (Sir George's) request. The members would find the works' brass foundries of very great interest. Messrs. Vickers deserved great credit for the figures which were quoted in the paper, and which were in a very large measure due to the unremitting efforts of Mr. Weeks himself. Since the paper was to act as a guide he proposed that it should not be discussed.

Crystal Growth and Recrystallisation of Metals.

The second paper taken dealt with "Crystal Growth and Recrystallisation of Metals." by Professor H. C. H. Carpenter, F.R.S., and Miss C. F. Elam. It was read in abstract by the former. We commenced an abstract reproduction of this communication on page 385 *ante*, and this we continue in the present issue, so that we need not refer to it specially here.

The discussion was opened by Dr. Rosenhain, who stated that he had read the paper with the greatest possible interest and pleasure, and expressed his admiration for the authors' skill in preparing it; the microsections it gave were the most beautiful he had ever seen. It paid him (the speaker) a great compliment in devoting much space to a review—or rather he would say a revision—of work carried out by himself and Sir Alfred Ewing about nineteen years ago. It was unnecessary that the authors should have made any excuse for doing this, for any work of that kind was not only open for revision but asked for it. The authors had been able to publish more photographs, than he could at the time he referred to. Dr. Rosenhain instanced lead cast in a form in which it had a minute structure relatively; then subjecting it to treatment did not produce any appreciable effect. Did it require minute measurements and highly-magnified photographs of crystals to show that there was no appreciable crystal growth in that class of metal? He did not think it did. The results of the authors confirmed the fundamental fact that the crystals of a casting of a metal which did not undergo internal transformation were not affected, as regards crystal growth or recrystallisation, by heat treatment. In opening their paper, the authors had stated that viewing the results as a whole, it was not possible to explain them by any of the theories which had yet been put forward. That was, he thought, a rather sweeping statement which, he also thought, could not be really satisfactory to the authors themselves. A former explanation of his (Dr. Rosenhain's) was to the effect that the crystals of a casting having been formed by a liquid were in quite a different condition of stability from those formed of growth in a solid, and this went a long way towards defining the difference. The authors had said that if the casting were not chilled one did not get conditions of stability; he did not agree with them there, and thought one did get these conditions. There were no solid surroundings to interfere with a regular arrangement and with the completion of the crystallisation of crystals to the utmost extent. In cast lead, on examining the slipbands they were found straight and regular; in the same lead on being recrystallised by cold work, there was a difference in the slipbands which were far from straight and regular. In beta brass exposed to the action of mercury, the crystals separated from one another if the material were cold worked. The real explanation was that in a cast material having a minute structure and cold worked there occurred a minute similar structure in a character of intercrystalline material; a movement occurred in the crystal boundaries different from that on a cleavage plane. What the paper indicated was that it did not raise difficulty in regard to an amorphous intercrystalline cement. Sir George Beilby's work illustrated that. It would be found that the facts could be reconciled by the amorphous hypothesis. The amount of energy in the crystal boundaries was not very large, and the displacement to be effected was too great for that energy to effect a movement without very considerable assistance and the realisation of specially favourable conditions. From one point of view, he was disappointed with the paper, its aim, he thought, was destructive; it refuted existing views and theories, but did not attempt to give others in their place. It was a safe course to pursue, but was not a helpful one, and he was sorry the authors did not give explanations of their own on the facts they had put before the meeting. He thanked them nevertheless for giving these facts.

Dr. Desch, who followed, said the paper was a most interesting and valuable contribution to the subject. It could not be said to be a destructive one; it was essential to clear the ground of misconceptions to be found in the literature dealing with crystal growth. The evidence in the paper was of a definite character, and although all the conclusions could not be accepted, knowledge had been carried forward by the authors' contribution. The authors had selected a good material for their researches, namely, tin and antimony alloys, which showed clearly the changes that took place. He found that they had overlooked a paper akin to their work, one by Robin, which has been published in 1914 in the *Journal de Physique*. Robin had examined a number of metals, and though Robin's conclusions, he thought, could not all be accepted, there was a large amount of valuable information in Robin's paper. He (the speaker) had studied such metals, and their solidification; one got double boundaries and could watch the migrations in subsequent heatings. He did not think we could get an explanation of the phenomena occurring when dealing with relatively coarse structures of crystal twins and slipbands. When one came to real internal construction of atoms, one would get nearer to the complete theory. One difficulty was the great slowness of any changes; when the surface was relatively small compared to the mass the surface energy was so small that the occurrence was slow. Bar iron and bar copper could become single crystals after sufficiently long annealing. With tungsten extended at a high temperature through a die, at a rate to keep pace with the velocity of crystallisation, one got a solid crystal. That should be the case with other metals and in other conditions, when giving full play to surface force. A great deal of evidence could be gathered from other substances apart from metals. Salts that crystallised from water could be obtained in a state of considerable strain. The strain could be removed afterwards by annealing. One could get strained conditions without the exertion of any external strain. He would not like to say that grain growth never took place in a cast metal; it was, no doubt, very much slower. He believed it could take place.

Dr. Hatfield endorsed the remarks which had been made by Dr. Desch. He also found that the authors' conclusions to the effect that crystals can

both grow and be grown into at one and the same time; that a large crystal may grow at the expense of a small one, or a small crystal at the expense of a large one; that neither similarity nor diversity of orientation affects the growth of one crystal into another; that the size of the crystals in a piece of metal that has reached equilibrium may vary within very wide limits; and that a large crystal does not necessarily invade a small crystal with which it is in contact; were all, in effect, conclusions which formed new and substantiated contributions to our study of the subject, and he congratulated the authors on their extremely valuable work in this respect. He also agreed with the authors when they said that growth took place by boundary migration and not by coalescence. He was not, however, satisfied at the moment that the evidence in favour of their conclusion to the effect that neither crystal growth nor recrystallisation will take place unless the metal has been subjected to plastic reformation, in the absence of change of phase, was final and unimpeachable. Metals from the same bath, when cast under dissimilar conditions, slowly or quickly, showed difference in the size of crystals. Since that took place, it would seem to him that there existed conditions under which crystals would grow; the conclusion of the authors in that respect therefore was, perhaps, not a final one. A statement of the authors was of great interest, namely, where they said that energy cannot be stored in the amorphous vitreous films which, according to Sir George Beilby, are the cause of work hardening in metals, because the growth of crystals in a worked metal proceeds after all mechanical softening has taken place; hence all the amorphous metal must have recrystallised. He (the speaker) quite agreed with that statement. He (the speaker) had already given the results of his experiments of cold work on brass; he had examined the crystals and found correlation of the structure with the stress. Before cold work the crystals could be seen under the microscope, and after the cold work had taken place one had crystal débris which were difficult to examine. On annealing at 200 deg. this state still persisted; at 250 deg. there was a rapid growth of large crystals, and at 300 deg. the recrystallisation from a number of centres became more emphasised. The mechanical softening actually proceeded up to 750 deg. He asked the authors for further data on mechanical softening in conjunction with the Brinell test; also what they really meant by "orientation of a crystal after reformation," a statement which drew a picture, but left one rather at a loss. In conclusion, he found that the authors had brought forward new data which they had put forward fairly, and he agreed with them that until much further knowledge in this field had been won we should not understand all the laws that governed crystal growth and recrystallisation.

Dr. F. C. Thompson wished to add his own congratulations to those of the previous speakers. The authors had said that the growth could take place of a small crystal into a large one. This was, he feared, a conclusion which had not been satisfactorily reached with the present evidence available. They had also said there was no evidence that on recrystallisation a total disintegration of the original crystal took place. Crystals of fair size did make their appearance at the boundary first. Distortion of the crystals at the boundaries took place during the deformation of the material. According to a statement made by Mr. Humfrey the boundary took a large part in the recrystallisation. There was a large amount of evidence that disintegration of the crystals occurred when the amount of work put upon the material was large, a statement which the speaker illustrated with slides of his own. The authors felt that the orientation of the crystals had no relationship to the crystallisation, but if Mr. Humfrey's interpretation in this connection was correct, then crystals of similar orientation grew into each other more quickly than crystals of different orientation.

Miss K. Bingham said the authors had stated that if a polished and etched specimen be heated at 150 deg. to 200 deg. C., and growth of any of the crystals took place, the position of the new boundary was marked by a line which was really a difference of level, almost as if the specimen had been etched, but there was no visible change in the surface of the re-oriented area. She asked whether the authors had tried placing polished specimens in the furnace without etching, and had found if any etching effects took place. She had tried with zinc and had a theory that a polished specimen of zinc would etch up.

Mr. F. Johnson asked whether it might not be possible that the authors had observed as small crystals were, perhaps, points of crystals sliced off, or just portions cut off and left unbedded.

In the course of her reply, Miss C. F. Elam said with reference to Dr. Rosenhain's statement in regard to the crystals of a casting that they thought like him, and would investigate the point further. So far there was no evidence that crystals did grow where there was no strain. No metal could be cut, polished and etched without the setting up of strain. The authors still held that there was no adequate explanation of the phenomena brought forward. If it were admitted that work was necessary for crystal growth and recrystallisation, one had to find out how that work affected the crystals. If work produced crystal growth, when that work became exhausted, the growth ceased. In the case of the tungsten example that had been given, the tungsten was being worked the whole time, and that was quite different from simply annealing the metal without any further work. If the metal were worked and annealed repeatedly one might end up in one single crystal. Dr. Desch had answered several of the points put by Dr. Rosenhain. With regard to some of Dr. Thompson's slides, the authors did find in some instances a marked roughened surface with a tarnished effect. The growing crystals started growing from the boundaries. When two neighbouring crystals had a different orientation, the etching affected them differently; when the orientation was similar the boundary was less marked. In reply to Miss Bingham the occurrence in a polished specimen placed in the furnace was, as Miss Bingham had stated, but the authors got the difference of level as they stated; and in reply to Mr. Johnson, the only thing she could say was that apparently small crystals grew into large ones and large ones into small ones. As far as could be seen there was no question as to size influencing crystal growth or the reverse.

Professor Carpenter stated that the criticism to the effect that the authors had not advanced explanations had, he thought, been answered by Dr. Desch. The authors had put forward as definitely as possible what they had found, and if their facts were accepted that was a first step in the matter with which they had dealt.

The Influence of Gases on High-Grade Brass.

The third paper taken dealt with "The Influence of Gases on High-Grade Brass," contributed by Mr. T. G. Bamford and Mr. W. E. Ballard. It was read in abstract, and we reproduced it in abstract on page 390 *ante*.

The discussion was opened by Professor Turner, who said that much attention had been devoted to the subject, both theoretically and practically for a number of years. It was natural when holes occurred in the metal to look to gas as the cause of the trouble. He had investigated in his laboratory the amount of gas obtained in melting brass in a vacuum and he had found the quantity to be a small one compared with the bulk of the brass. Other experiments with steel showed there was a large amount of gas compared with the bulk of steel. There had also been experiments by Professor Carpenter and Miss Elam, who had found that in regard to the amount of gas in the case of molten Admiralty bronze the time-effect came in. The extraction of the gas in vacuo and the analysis of that gas did not actually show the character of the gas in the metal. The present authors had carried out a good series of experiments covering various gases, and they dealt with the question of solubility (of hydrogen in brass, for instance), and with that of the behaviour of the gas. There was the remarkable action of sulphur dioxide, the occurrences at various heatings, and so forth. Their results were comparable to those of Professor Carpenter and Miss Elam, who had said that the temperature of pouring came in and was important. The authors had experimented in various atmospheres, and their work had shown the possibility of obtaining sound castings in connection with any gas, provided the melting, the pouring and the mould were right. A most essential point was the proper pouring temperature. This was the first paper to come from the Research Department of the Brass and Copper Tube Association. Now the British Non-Ferrous Metal Research Association was formed, and it was hoped it would benefit the trade and lead to a prosperous future.

Captain J. Cartland said he had carried out a large amount of work in the same direction and knew the difficult nature of that class of work. He had heated the metal in vacuo and had poured it into a greased mould and into a mould not greased. The object of greasing the mould had reference to the function of the grease in the stripping. He could not find any essential difference in the gases in the two instances. The greasing led the air to slide up the inner surface of the mould.

Dr. Hadfield thought that the experience in another realm of metallurgy could come in in the instance under consideration. In the metallurgy of steel, small additions of silicon and manganese prevented the occlusion of gases during freezing. He asked whether, if the chemical side were gone into more closely, and not so much stress laid upon the question of temperatures, the matter would not be more advanced.

Mr. F. Johnson found that the paper would be of great assistance in leading to the making of sound castings on a commercial scale. Inference, he thought, might be drawn from the authors' figures that 70:30 brass was more susceptible to gases than copper or zinc; but copper was much more susceptible than 70:30 brass. This applied, for example, in welding. The authors should make the point clear. In one type of porosity of which he had seen instances there appeared to be release of gases in solidifying in the case of billets and castings, there occurring brittleness such as was shown in an alloy having eutectic films. He thought some samples of that kind were referred to in the paper by Professor Carpenter and Miss Elam. Sulphur dioxide was responsible for much of the trouble that was encountered. A paper by Sgombrowski would be of great assistance.

In the course of his reply to the discussion, Mr. Bamford said they had started their work under the impression that gases were the cause of porosity in the castings, and such was probably the case. They had found gases present in unsound castings. They had traced a large amount of sulphur dioxide and oxygen reabsorbed, and had found it necessary to exclude those gases. They were surprised, on the other hand, to find that if the metal were cast at the right temperature the gases did not matter. One sample of 70:30 brass cast at a low temperature in the presence of sulphur dioxide showed a fracture full of black holes, but this when re-melted gave a good surface. They had also tested the forging properties. They emphasised the importance of the casting temperature. They had also tried whether with the addition of manganese and a low temperature they could obtain sound metal; they had not obtained sound metal, this being just as bad as when no manganese was added. With reference to Mr. Johnson's remark as to the susceptibility of brass to gases, hydrogen notably, they (the authors) had safeguarded themselves at that part of their paper dealing with the point and Sievert's results by adding "if Sievert's results are correct."

The Constitution of the Alloys of Aluminium and Magnesium.

The fourth paper taken was on "The Constitution of the Alloys of Aluminium and Magnesium," by Mr. D. Hanson and Miss M. L. V. Gayler, the latter reading it in abstract. It pointed out that the equilibrium diagram by Grube—16, the only one previously available, was incomplete. The authors showed that it needed considerable revision, and they had worked out the complete constitution over the whole system of alloys. They showed also that aluminium and magnesium formed two compounds with each other, one had the formula Al_2Mg_3

(37 per cent. of magnesium) and the other probably had the composition Al_2Mg_3 (57 per cent. of magnesium).

The discussion was opened by Dr. Desch, who said that the Grube diagram was a typical diagram obtained with impure materials, examined in a hurry and not with a good pyrometer. The authors' work was on a line with that which was expected in this country. He called attention to the cusp in the authors' curve, Fig. 21, at the range round about Al_2Mg_3. As far as he could see it was theoretically necessary that where the point occurred there should be a common tangent to the liquidus and solidus; one would expect the common tangent to be horizontal. The higher cusp shown in the solidus was, he thought, theoretically impossible.

Dr. Rosenhain, who followed, said he had seen the research grow; it had taken an enormous amount of time and work. He fully realised that the portion of the curve referred to by Dr. Desch was, possibly, not the last word on the subject. But the settling of the point was surrounded with exceedingly great difficulties, there being such slight differences in the percentage contents of the alloys, and, at the same time, such slight differences in the temperatures. There might be, as he explained, a compound at 54 per cent., and one could draw a diagram imagining a vertical line, the solidus sloping away by the side of it. He (the speaker) agreed with the course taken by the authors in simply stating the results and not attempting to bring them into line with phase rule requirements.

Dr. A. G. C. Gwyer, referring to Dr. Desch's remarks, thought that no one who worked in laboratories would feel hurt at knowing that early work might be revised later on. Previous work had a different aim in view and was not carried out from the standpoint of metallography. Tammann was interested in intermediate compounds, and the reason why most papers dealt with such compounds was the one he suggested rather than the formation of solidus solutions. With regard to the diagram, Fig. 21, of the authors' paper the only point open to controversy was the formation or non-formation of Al_2Mg_4 and the formation of a new compound Al_2Mg_3. He congratulated the authors on the caution with which they put forward their views. There was no evidence of an arrest at the point referred to in their curve, and he remained sceptical as to whether Al_2Mg_3 existed.

Mr. Q. A. Mansuri, referring to the authors' diagram, Fig. 4, said he had worked with aluminium alloys of various degrees of purity, 99·7 per cent. for instance, and had found the freezing-point not so definite as in the case of other metals, such as silver and copper. He asked the authors whether their freezing-point was a definite point or a freezing range; in one case the range extended over about 40 deg.

In replying, Mr. Hanson said that the aluminium alloys they had dealt with were of interest to Barrow, where they were largely used. In regard to the melting-point, it was agreed that for commercial aluminium it was not definite, but extended over a range due to the iron contents and specially to the silicon. Point A in their diagram, Fig. 4, was the beginning of solidification on cooling, and the fact that freezing did not take place at a constant temperature was attributable to the impurities. In the diagram, Fig. 21, the difference was of the order of 5 deg. C. They would have liked to find a definite 'melting-point, when they could have made a different diagram. They had, however, sufficient faith in their methods to believe that 5 deg. in temperature made a definite difference. They had repeatedly obtained the same results and were convinced of their accuracy.

MAY LECTURE.

At the close of Wednesday morning's meeting, the President announced that the May Lecture next year would be delivered by Professor Turner, who would deal with the "Casting of Metals." For the, delivery of these lectures, the Institute had always looked for a master of his subject in non-ferrous metal work, and had always been successful. They had followed the same course in this case, and the Institution was to be congratulated upon Professor Turner's acceptance of the invitation.

THE EFFECT OF INCREASING PROPORTIONS OF ANTIMONY AND OF ARSENIC RESPECTIVELY UPON THE PROPERTIES OF ADMIRALTY GUN-METAL.

On the members reassembling on Thursday morning, the 16th inst., the first paper was that having the above title, contributed by Mr. R. T. Rolfe, who read it in abstract. We hope to publish this paper in a future issue.

The author said he found that in sand-cast gun-metal antimony progressively increased the hardness and decreased the strength and ductility. If a proportion of about 0·75 per cent. was exceeded the minimum specification figures for tensile strength and elongation might not be reached. Chill castings showed the same tendency in a modified degree. Antimony had no effect on the soundness of the castings except in the case of chill-cast metal melted twice, when, with increasing antimony was associated increasing unsoundness. To avoid this a figure of 0·75 per cent. must not be exceeded. No effect on the microstructure could be observed. In the case of sand-cast metal melted once, increasing arsenic caused a falling-off of both strength and ductility. A maximum figure of 0·3 per cent. was suggested. In re-melted metal, this effect of arsenic was rather masked. Arsenic had no effect on soundness except in the case of chill-cast metal melted twice, when increasing arsenic was associated with increasing unsoundness. A maximum figure of 0·4 per cent. was suggested. Arsenic had no influence on the hardness. The arsenic figure influenced the microstructures in sand casting but not in chill castings.

Sir George Goodwin, in opening the discussion, said that Mr. Rolfe's works supplied gun-metal castings to the Admiralty, and the Admiralty specifications asked for new metals; he (the speaker) was surprised at the results given by the author for both antimony and arsenic, which pointed to the risk of disagreeable features.

Mr. F. Johnson said the author had referred to a paper of his (the speaker's) read two years ago, a paper which dealt mainly with explorative work only. The author had thrown a new light on the subject and on actual foundry conditions. He (the speaker) was not able at the time to obtain his castings in normal works' conditions. His own work was more on the line of die castings. Under different foundry conditions it was possible to produce even better results than the author had shown. He (the speaker) referred to a paper by Carr, an American, who obtained high figures for both tensile strength and elongation, but he could not say whether the bars were cast horizontally or vertically. The author's bars were cast vertically, and that had somewhat influenced his results. Casting horizontally would give better physical properties. Arsenic should not be condemned wholesale. The composition of the added elements might be an important factor, and in this connection sulphur might be a disturbing cause.

Mr. L. Archbutt found that Mr. Rolfe had done good service by continuing his work on the subject, and had cleared up some points which had been left in doubt. In regard to the effect of small quantities of antimony or gun-metal, he (the speaker) had made experiments some years ago which confirmed the author's conclusions, but differed from his results to some extent. Three melts were made of gun-metal of Admiralty composition, but containing about 2 per cent. of lead, and in two of the melts antimony was added in such proportion as to give about 0·5 per cent. and 1 per cent. in the alloy. Three ingots of each alloy, weighing about 13 lb. each, were cast in sand, and three test bars were prepared from each ingot. The turnings from the test bars were assayed for antimony. The following mean results of the three bars of each ingot were:—

Ingot A: Antimony, 0·025 per cent.; maximum stress, 13·37 tons; elongation, 20·40 per cent.
Ingot B: Antimony, 0·47 per cent.; maximum stress, 14·53 tons; elongation, 20·73 per cent.
Ingot C: Antimony, 0·92 per cent.; maximum stress, 11·13 tons; elongation, 9·27 per cent.

The figures for maximum stress were lower, and for elongation higher than the author's, owing perhaps to the lead on the alloy. With 0·5 per cent. of antimony, the results were rather better than with the metal free from antimony, but with 1 per cent. there was a marked decrease of stress and ductility. A point he (the speaker) noticed, but which the author appeared not to have observed in his sand-cast bars, was a marked unsoundness in both the alloys containing antimony. Discs were turned off the ends of each test bar and the unsoundness was observed by micro examination of the polished faces of the discs. The speaker added he was rather surprised at the author's reference to antimony in commercial tin. On looking through the analyses of 35 samples over a period of seventeen years he could find only one sample having more than 0·71 per cent. of antimony, and that was a Bolivian brand which contained 4·4 per cent.

Mr. E. R. Taylor congratulated the author on his work dealing with the effect of impurities on gun-metal, and stated that his results would be found useful by practical men working under actual foundry conditions, which were different from those prevailing in laboratory practice. The question of arsenic had long been a vexed one. The results recorded in this paper would have proved most valuable had they been available during the war period, when there was absolutely no time whatever available for carrying out proper scientific researches. Referring to the author's micrograph of a bar containing 1·01 per cent. of arsenic he thought several places showed a tearing-out effect during polishing, there being small areas of a brittle constituent. He (the speaker) had had an instance of a gun-metal having a high proportion of arsenic and on etching a specimen there were seen under the microscope a number of diamond points in relief. The Admiralty made the suggestion that the diamond points might be the cause of strippings occurring on the heel of a connecting rod. He asked whether the author in his synthetic alloys had come across such diamond points. The acid ferric chloride used by the author as an etching medium had the effect of darkening the samples and perhaps rendered examination under the microscope less easy. The author had said that no appreciable differences in structure could be noted as the proportion of antimony increased; it was important, therefore, that the antimony should be determined by chemical analysis, and in estimating the tin due regard should also be had to the antimony and the two should be returned separately.

Mr. Rolfe, in the course of his reply, said that varying proportions of impurities might occur in new metals and prejudice the results. Cheap metals might have a high percentage of arsenic and other impurities also. Brands of tin might also contain lead and antimony to a high degree. It was necessary, therefore, to arrive at the limiting proportion, the material being passed if right, or rejected. The test figures by Carr could be obtained by him (the speaker). The figures he had given in the paper applied to his work; they applied to vertical cast bars, and covered the particular metal he was then producing. The ultimate use for which a piece was destined had to decide the way in which a casting had to be made. When wear came in, hardness was required, a low elongation metal giving better wearing properties. He was not so prejudiced against arsenic as against antimony, but was not prepared to say it might have a beneficial effect. Sulphur might cause the evolution of a greater volume of gas during the second re-melt. It was necessary to keep antimony out as much as possible, sulphur might be present in the antimony.

The President said the author had set his mind at rest in his reply. The discussion would have the effect of leading the Admiralty, when they asked for new metal, to see that they got what they meant.

SERVICE EXPERIENCE WITH CONDENSER TUBES.

The second paper taken at Thursday's meeting dealt with "Service Experience with Condenser Tubes," by Engineer-Lieutenant-Commander G. B. Allen, R.N., who read it in abstract. We publish this paper, in full on page 423 of the present issue.

Professor Carpenter, who opened the discussion, said it was a satisfaction to the Committee on

METAL-FRAMED MOTOR OMNIBUS BODY.

CONSTRUCTED BY MESSRS. THE AIRCRAFT STEEL CONSTRUCTION COMPANY, ENGINEERS, LONDON.

(*For Description, see opposite Page.*)

Fig. 1.

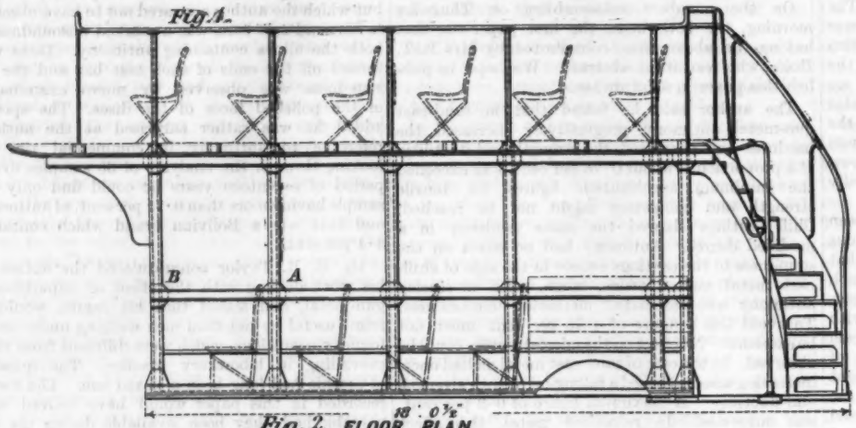


Fig. 4. FRONT

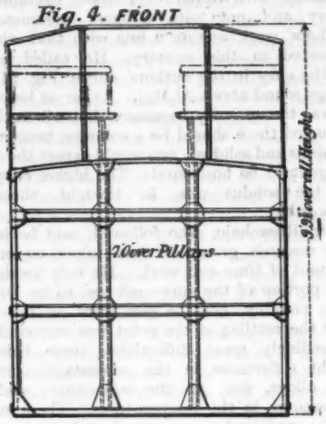


Fig. 2. FLOOR PLAN

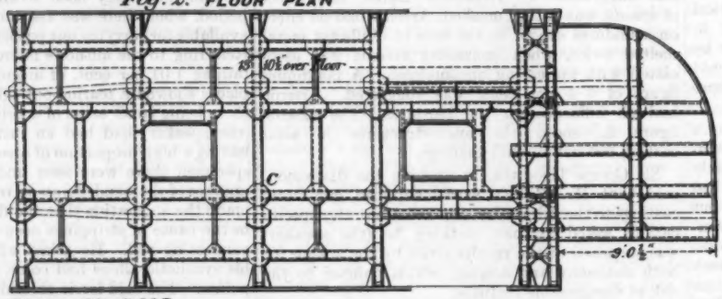


Fig. 5. REAR

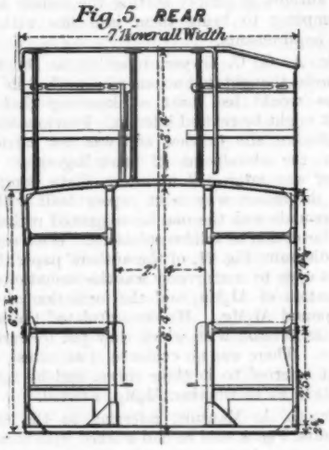
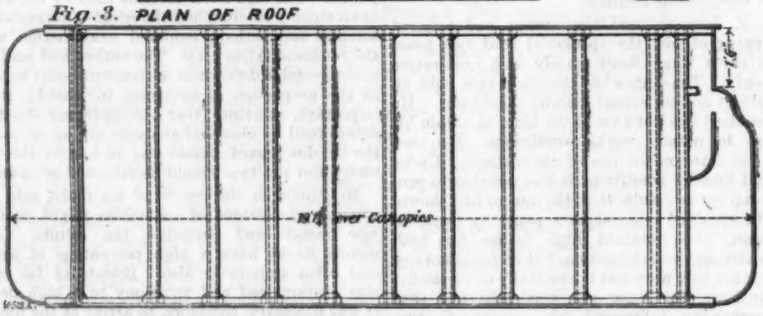


Fig. 3. PLAN OF ROOF



Corrosion to have this paper from the Admiralty. In regard to the Cumberland process, the author had stated it had been fitted in certain vessels, but beyond the fact that it had been found that it had not arrested decay where such decay had been in evidence before the process had been installed, the experience gained had not been sufficient to allow of any reliable conclusion being drawn. Professor Carpenter asked whether the Admiralty had any experience of the process where decay had not actually set in. For some time, the Corrosion Committee had been attacked in the Press for not using the Cumberland process, saying that it contained the solution of the difficulty. So far as the present paper went, it justified the attitude taken by the committee. There were cases where the process was applicable, but it was not stating the matter fairly to say that the Cumberland process was a cure. The causes of corrosion were so manifold that there was no one cure for corrosion. He (the speaker) was glad the paper referred to the oxide film suggested by the committee, and was sorry that the vessel, the condensers of which was fitted with tubes having such a film, had done as yet too little steaming for useful data as to the efficiency of the film to be obtained.

Dr. G. D. Bengough said he had read the paper with interest, and with a great deal of it his own experience agreed. A few points, however, were not identical with his views; the conditions on land and in the Navy were not likely to lead to the same experiences. As to the causes of deterioration the fact stated by the author, namely, that deterioration at the inlet ends accounted for 18 per cent. of the total failures, was an important point. The author had said that erosion took place and the remedy was to find a tube having a great resistance to erosion. He (the speaker) thought the trouble had a different origin altogether. Here Dr. Bengough exhibited three lantern slides. A tube end showed the accumulation of salts at the end of the tube under the ferrule. Air bubbles collected between the end of the tube and the recess in the ferrule, and when attack had started there it had a tendency to spread to the inside of the tube. There was a settling at the bottom of the tube, and this might be the origin of the trouble. In order to do away with this condition, the tube was made to butt against the ferrule; but there being still a slight space for the accumulation of air, he made the ferrule slightly bell-shaped, to give a smooth flow and eliminate the air space at the inlet end. The author did not say that spills or laminations gave rise to pitting, but only that such was the prevailing opinion. The Corrosion Committee had done work on spills and laminations and had obtained negative results except in one case only, and they concluded that spills and laminations did not initiate corrosion; nevertheless, spills and laminations were not to be tolerated, for they might come into play later, and a tube with a spill was weak. Such defects were to be avoided although they could not be correlated with pits. The author had shown that very much trouble was due to "general corrosion"; he (the speaker) was not clear as to what was meant by that general term. More definite terms should be used. It was sound practice to use mild steel slabs bolted on to the boiler plate rather than depend upon the bare water end for protection.

Lieutenant-Commander Allen, in the course of a brief reply, which he stated he would extend in the proceedings by correspondence, said the experience gained with the Cumberland process was covered by the remarks in the paper. Ferrules with a rounded edge were not fitted in ships, but with ferrules having the inlet ends elongated and a rounded edge, he thought that corrosion would be transferred to that part, a measure which was successful. Under "general corrosion" he had put down all types of corrosion which did not come under the other seven headings.

Some Features in the Behaviour of Beta Brass when Cold-Rolled.

The third paper was the one having the above title, by Mr. F. Johnson, who read it in abstract.

It described the mechanical properties of a brass having 55·6 per cent. of copper, before and after cold-rolling. The alloy consisted entirely of crystals of the beta phase, no free alpha being

METAL-FRAMED MOTOR OMNIBUS BODY.

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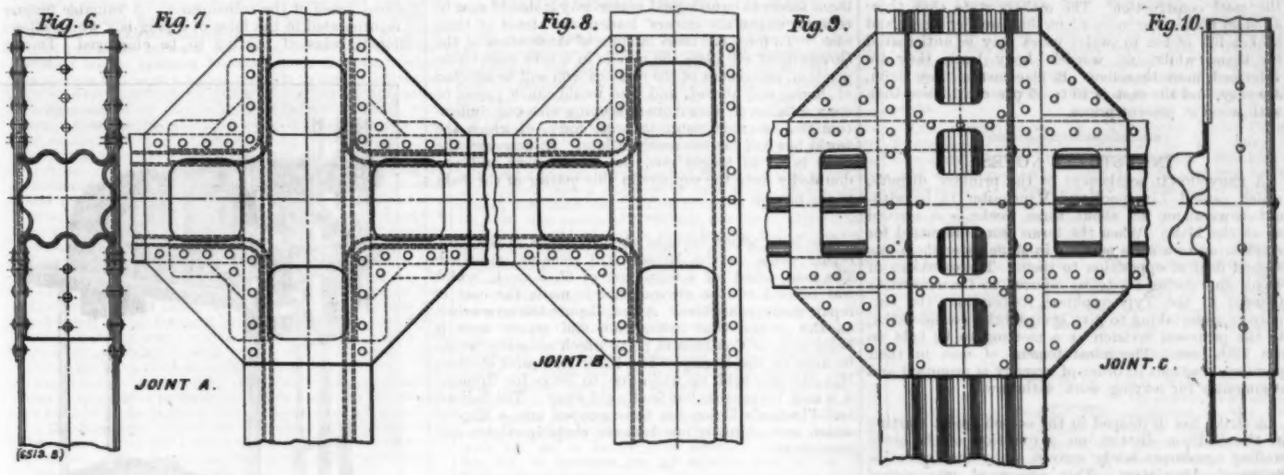


observable. A reduction of 50 per cent. in rolling cold resulted in the raising of the tensile strength from 22·6 tons to 38·2 tons per square inch, the elongation falling from 27 to 8·5 per cent.

Dr. Rosenhain thought that the real nature of the lines found in the microsections after cold work on the material required further investigation; the study of the markings was well worth pursuing and he hoped Mr. Johnson would continue his researches.

Dr. G. D. Bengough referred to the paper he contributed in conjunction with Mr. Hudson to the Journal of the Society of Chemical Industry, on the beta phases, and containing photographs similar to Fig. 8 of the author's paper. In regard to the author's Fig. 2, he (the speaker) considered the nodal markings on the lines to be alpha crystals separating out on the gliding planes. As for the author's microsections, Figs. 11 and 12, he (the speaker) thought the lines shown were due to an etching effect amd did not represent a definite structure, whilst Figs. 13 and 14 were real structures. A most interesting diagram was the author's Fig. 20; Dr. Bengough did not see that effect in his former work.

Dr. Desch said in etching brass after cold work he obtained similar structures to those recorded by the author, and he assumed the lines to be planes parallel with the cleavage planes. He (the speaker) recently took up again a sample which had been laid by for three years; as it was tarnished he re-polished it, but the lines had disappeared, and to get them back again he had to re-strain the specimen. He did not think that could be the case with Neumann lines.

Mr. Johnson, in replying, said he agreed with Dr. Rosenhain that further investigation was necessary, but he was afraid he would not be able to carry it out. This present work was, as it were, a by-product of other work. In the figures referred to by Dr. Bengough there was no smear effect, real etching bands were shown.

NOTE ON A FAILURE OF "MANGANESE BRONZE."

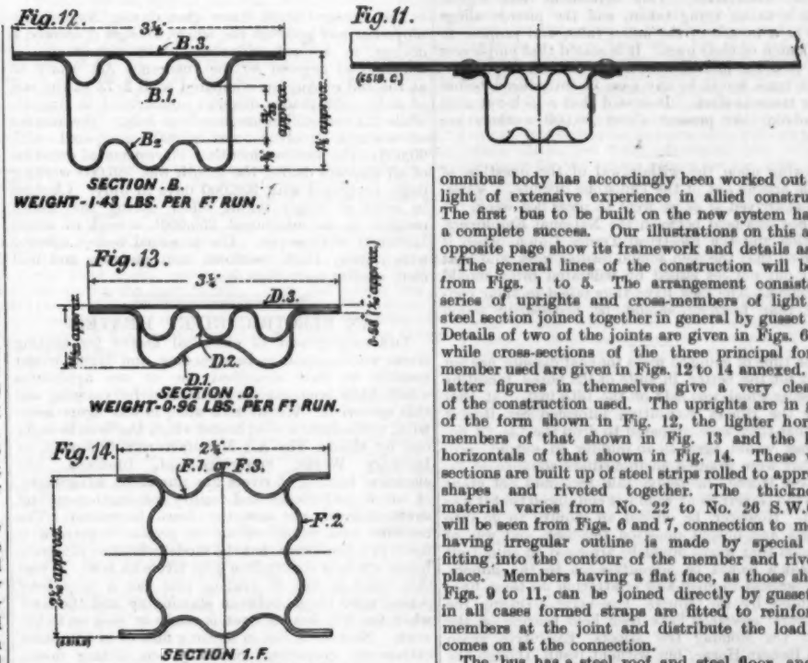
The fourth paper was a "Note on a Failure of 'Manganese Bronze,'" by Mr. J. H. S. Dickenson, who read it in abstract.

It stated that the examination of a "manganese bronze" end plate from a turbo-alternator rotor which failed in service showed that certain fractured peripheral projections had been rendered brittle by the contact of fluid solder which had penetrated along the junctions of the crystalline grains. This led to the experiments which the author described.

Dr. Rosenhain found the paper of great interest as dealing with a subject which was receiving tardy attention, and detailed similar occurrences.

The papers taken as read were the following: "The Allotropy of Zinc," by Miss K. E. Bingham; and "The Constitution and Structure of Certain Tin-Antimony-Copper Alloys," by Dr. O. F. Hudson and Mr. J. H. Darley. On the motion of the President, all the authors received the thanks of the meeting for their contributions.

Votes of thanks to the Mayor and Corporation of Barrow, and to the works and establishments who had entertained the members, terminated the proceedings. The President announced that the next general meeting would be held in London on March 9 and 10, 1921.



METAL-FRAMED MOTOR-OMNIBUS BODY.

A REMARKABLY interesting metal framework for motor-omnibus bodies is being introduced and manufactured by The Aircraft Steel Construction Company, of 39, Victoria-street, London, S.W. 1. The form of construction embodied may be looked upon as a development from the steel construction for aircraft which was worked out during the war. Mr. James Mayrow, to whom the present design is due, was associated with one of the earliest and most successful steel aircraft designs, and the motor omnibus body has accordingly been worked out in the light of extensive experience in allied constructions. The first 'bus to be built on the new system has been a complete success. Our illustrations on this and the opposite page show its framework and details as built.

The general lines of the construction will be clear from Figs. 1 to 5. The arrangement consists of a series of uprights and cross-members of light rolled steel section joined together in general by gusset plates. Details of two of the joints are given in Figs. 6 to 11, while cross-sections of the three principal forms of member used are given in Figs. 12 to 14 annexed. These latter figures in themselves give a very clear idea of the construction used. The uprights are in general of the form shown in Fig. 12, the lighter horizontal members of that shown in Fig. 13 and the heavier horizontals of that shown in Fig. 14. These various sections are built up of steel strips rolled to appropriate shapes and riveted together. The thickness of material varies from No. 22 to No. 26 S.W.G. As will be seen from Figs. 6 and 7, connection to members having irregular outline is made by special straps fitting into the contour of the member and riveted in place. Members having a flat face, as those shown in Figs. 9 to 11, can be joined directly by gussets, but in all cases formed straps are fitted to reinforce the members at the joint and distribute the load which comes on at the connection.

The 'bus has a steel roof and steel floor, and apart from the seats and smaller fittings is in its main features all-steel construction. There is, of course, nothing to prevent wood panels being fitted, and we believe three-ply wood has been found suitable for this purpose. The steel roof as fitted to the 'bus with which we are dealing has, however, been entirely satisfactory. It is of 22 S.W.G. material. The floor is of 24 S.W.G. at the sides and 22 S.W.G. in the middle. It is interesting to note that the weight of the steel roof, including the supporting cross-members, is 193 lb. This compares with a corresponding figure of 244 lb. for the three-ply wood roof. The steel body all complete weighs 19 cwt. It accommodates 46 passengers and is of the new "K" type of the General Omnibus Company.

A single-decker body of this class, to carry 32 people, and arranged with all windows to open, weighs 16 cwt., and a special single-decker for tropical service with all-steel parts treated with electrolytic zinc weighs 17 cwt. This latter weight compares with 30 cwt. for a standard body built in teak. It will be evident that this steel construction makes a great saving in weight possible with consequent saving in petrol consumption and tyre wear. The advantages of the construction do not however stop there since it lends itself well to rapid construction in large quantity. The various sections are all rolled to finished size, and with a proper equipment of riveting-up jigs the fitting and hand work is reduced to a very small

amount. The final appearance of a finished 'bus differs in no way from that given by the more usual forms of construction, and the assembled frame is as rigid as a wooden one, if not more so. It is important to note that no reliance is placed on the panelling to take any load or to contribute to the stiffness of the steel construction. The makers state that these all-steel bodies are more silent than wooden ones, and that a life of ten to twelve years may be anticipated for them, whilst no wooden body lasts, they are informed, more than five. Replacements, they claim, are easy, and the cost is 10 to 15 per cent. lower than with wood at present prices.

INDUSTRIAL NOTES.

A PROVISIONAL settlement of the printers' dispute, which caused Liverpool and Manchester to be without newspapers for about three weeks, was arrived at on the 17th. When the terms were submitted for ratification to a mass meeting in Manchester there was a good deal of opposition to them. The questions of wages and status are to be referred to the Executive Council of the Typographical Association, the employers undertaking to give sympathetic consideration to the proposed revision at a meeting to be held on the 29th inst. The reinstatement of men in their previous positions in order of urgency is promised and summonses for leaving work withdrawn.

A strike has developed in the cotton trade, starting in the Oldham district, on a question of the mule staffing agreement lately arrived at by the Operative Spinners' Association. This agreement was signed without a ballot being taken, and the piecers allege this to be a breach of the union rules, and propose to form a union of their own. It is stated that employers do not view the matter with much concern at present, as short time would in any case be introduced before long, as trade is slack. It is said that a lock-out may be involved. At present about 30,000 workers are affected.

Following upon the withdrawal of the question of principle arising out of the Penistone dispute, a settlement was arrived at as we went to press last week. A conference was held between the National Employers' Federation and the Electrical Trades Union, when it was agreed that the men should resume work, and that the lock-out notices issued by federated firms should be cancelled. The men have thus failed in their contention that foremen should be necessarily union men.

At the time of going to press the coal dispute has not changed for the better, in spite of the hopes raised by the meeting which was held on the 16th inst. At that meeting the Miners' Executive informed Sir Robert Horne that they were prepared to drop the 14*s.* 2*d.* demand, but would agree to an inquiry on output, provided they were granted an immediate advance of 2*s.* Sir Robert Horne, in reply, said he could not grant that, as the Government were not convinced that it was justified. However, he offered an inquiry to go into the wages and output question together, and was of the opinion that wages might be arranged on an output basis, which would be advantageous to the miners. An independent inquiry and arbitration on these lines was refused by the Miners' Executive. During the week several meetings have been held bearing on the subject. On Monday the Miners' Executive again met Sir Robert Horne, but without result, though the President of the Board of Trade further explained his offer. On Tuesday, among other meetings, was one held by the General Council of the Transport Workers' Federation. At this the action of the Miners' Executive was approved. The Miners, Transport Workers, and Railway unions met for a joint conference on Wednesday.

At this meeting on Wednesday, the so-called Triple Alliance decided to support the miners' demands. A deputation was arranged to meet the Prime Minister the same evening, consisting of the Miners' Executive, with Mr. Thomas and Mr. Cramp, representing the railwaymen, and Mr. Gosling and Mr. Williams the transport workers. The interview unfortunately left matters much where they stood before. The Prime Minister supported Sir Robert Horne. He asked the miners' executive to agree to arbitration on their 2*s.* demand, or to meet the coalowners to discuss output as a basis for wages. At the suggestion of Mr. Bonar Law, Mr. Lloyd George proposed that they should do both, but the men's leaders refused to accept arbitration for wages, or to consider the second point until the first demand was conceded. It will be admitted that Mr. Lloyd George adopted a very fair attitude on the matter of wages. His contention is that on the Government's figures the advance is not justified, and that, in its opinion, the miners have profited more than any other trade by recent advances. He is, nevertheless, willing to submit to an impartial tribunal. When figures are interpreted in two such different ways by interested parties the only possible solution would appear to be to refer the matter to an umpire. Arbitration has been accepted in so many trades, the miners themselves having had it before the war, that there seems to be no logical reason why it should now be refused, unless the miners' leaders are afraid of their case. To force the issue in spite of these offers of the Government will place the miners in a very unenviable position, on account of the millions who will be affected at home and abroad, and who would much prefer to see a solution on lines more in keeping with our civilisation than a crude resort to brute force, of which the world has had far too much of late. If, however, the issue is to be fought out, the Government will undoubtedly have the support in this matter of the bulk of the nation.

The issue which brought about a strike in the ship repair yards on the Mersey still remains unsettled. The men asked for a minimum of 6*l.* a week, which was refused on the ground that it made the cost of repair work prohibitive. A new dispute has now arisen on the ground that recondition and repair work is being done in Continental ports which normally would be done on the Mersey. The Elder Dempster steamer Monarch was held up when due to leave for Bremen, it is said, for repairs, but finally got away. The Sailors' and Firemen's Union has thus stepped into a dispute which was originally one between the shipwrights and employers.

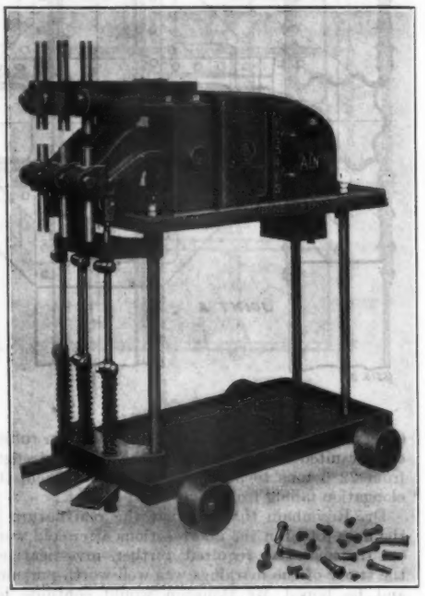
The *Labour Gazette* states that during August employment was good on the whole, though it showed a decline in several industries. The percentage of unemployed covered by the Insurance Act was 2·88 at the end of August, compared with 2·73 at the end of July. 139 trades disputes commenced in August, while 123 were still in progress from July. The number of workers involved was 86,000, compared with 90,000 in the previous month. The estimated duration of all disputes during the month was 786,000 working days, compared with 908,000 days in July. Changes in rates of wages taking effect during the month resulted in an additional 250,000*l.* a week to about 1,100,000 workpeople. The principal bodies affected were railway traffic workers, iron puddlers and mill men, woollen operatives, &c.

AN ELECTRIC RIVET HEATER.

THE employment of electrical means for heating rivets would appear to be spreading, and during recent months we have described one or two appliances which have been put on the market for carrying out this operation. We are now able, in the figure herewith, to illustrate a rivet heater which has been brought out by Messrs. The A.1 Manufacturing Company, of Industry Works, Sunbridge-road, Bradford. The electrical heating of rivets has numerous advantages, of which convenience and facility for starting-up and shutting-down are not the least important. The machine with which we are at present concerned is made in several sizes, but the model which we illustrate below will heat six hundred ½-in. rivets an hour. From this figure it will be evident that but a very brief period must elapse between starting-up and the time when the first heated rivet is ready to pass on to the work. No time is lost in lighting fires or in any other extraneous operation. Similarly, on closing down, rivets may be heated up to the last moment, and when the last has been taken out, the machine may simply be left and will be at once ready for starting up again for the next shift. Another important feature in the electrical heating of rivets is that the rivets being dealt with are in full view of the operator all the time, so that loss from burning or overheating is prevented. It is, of course, possible to overheat a rivet by leaving it too long in the machine, but such overheating can only result from gross carelessness, and the conditions are very different from those in which the rivets are more or less buried in a fire. The loss of rivets from burning and overheating is much less with electric heating as compared with the use of fires.

The heater which has been brought out by the A.1 Manufacturing Company is a very simple piece of apparatus, not at all likely to give trouble. As will be seen from the illustration it consists of a simple framework on wheels carrying the transformer and heating unit at the top. Three jaws for heating rivets are provided, and consist of straight lengths of copper rod which may be fed forward to suit the length of rivet or as they are gradually burnt away. The upper of each pair is fixed, and the lower is carried on a pivoted arm which is controlled by a pedal and springs. Depression of the pedal opens the jaws so that a rivet may be inserted, while the spring normally exerts an upward pressure on the lower jaw and so holds the rivet in place. A flexible connection to the lower side of the arm conveys current to it and the pivot carries no current.

There are no switches to open and close in the normal operation of the heater, and when no rivets are in place no current is passing, and there is no consumption of energy other than that due to the no-load losses of the transformer. A valuable feature is incorporated in the form of a plug-box which allows different rates of heating to be employed. During



temporary slowing-up in the rate of consumption of heated rivets, it is a great convenience to be able to plug on to the slow rate of heating and so for the time reduce the rate of output of the machine. The standard winding is arranged for a supply voltage of 200 at 50 periods, single-phase, and the maximum capacity of the machine we illustrate is 15 kw. Although it is clearly not desirable to push the matter to extremes, larger rivets may be heated by utilising only two, or even only one, of the pairs of jaws.

THE INSTITUTION OF GAS ENGINEERS.—We learn that on and after September 29 the address of this Institution will be: 30, Grosvenor Gardens, Westminster, S.W. 1.

AIR MINISTRY COMPETITIONS, 1920: ERRATA.—We have received from the Air Ministry the following corrections to the table of data of large and small aeroplanes competing in the trials at Martlesham Heath, which was published on page 343 *ante*. In the case of the Handley Page "W. 8" machine the indicated cruising speed should be 80 m.p.h. instead of 84 m.p.h., and the actual cruising speed 84 m.p.h. instead of 88 m.p.h. In connection with the Austin "Kestrel" machine the landing distance in yards from the mark should have been 204 instead of 244.

THE INSTITUTION OF NAVAL ARCHITECTS: SCHOLARSHIP AWARDS.—The Martell scholarship in naval architecture (1920) has been awarded by the Council of the Institution of Naval Architects to Mr. H. K. Rodgers, of Chatham Dockyard, and the Earl of Durham prize to Mr. A. Beale, of Portsmouth Dockyard. The post-graduate research scholarship in naval architecture offered by the Royal Commissioners of the 1851 Exhibition has been awarded by the Council of the Institution of Naval Architects to Mr. E. V. Telfer, B.Sc., on the nomination of Armstrong College, Newcastle-on-Tyne.

WAR TRANSPORTATION NUMBER OF THE "RAILWAY GAZETTE."—The *Railway Gazette* has just issued a special number devoted to a description of transportation during the recent war. This forms a very interesting record, running to some 160 pages of matter, including a series of excellent illustrations. The number opens with short editorial summaries on a variety of subjects drawn from sources near at home and far afield. The bulk of the issue is taken up with descriptive articles on such topics as the organisation of the Transportation Directorate, Railways and Roads in France, the B.E.F. Base Locomotive Shops, Railways in the Italian Theatre, at Salonica, in Palestine and Mesopotamia. Inland water transport also comes in for a reasonable share of attention. The issue forms the first real attempt to make an adequate survey of one of the most vital services of the war, and while any such attempt must be subject to certain limitations, the *Railway Gazette* is to be congratulated on the material it is now able to place before its readers in an interesting collective form.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—In the heavy engineering section, purchases on both home and export accounts are almost solely limited to essential requirements, chiefly for renewals of plant. Few buyers on the Continent are placing orders for renewals of machinery steel and tools with Sheffield makers at the moment. The tendency is either to take advantage of America's ability to quote fixed prices for forward deliveries, or to wait until the British labour position becomes more stabilised, when producers will be in a better position to ensure deliveries. In several branches of trade the effect of industrial reorganisation in countries that before the war were competitors to be reckoned with, is more severely felt in competition for export business. File makers, for instance, have experienced a record run of activity and prosperity. To-day, home trade is declining owing to the contraction of business in engineering requirements, and foreign buyers are looking askance at some of the latest local quotations given, which do not compare favourably with the rates at which American manufacturers are prepared to deliver goods of similar quality. Foreign under-cutting for big business in steel rails and fishplates for tramways is a feature of the position. An order for 11,000 tons quoted for at 28*l.* per ton in this district, has been taken by America at 23*l.* 10*s.* per ton delivered. The demand for tool steels is decidedly quiet, but the saw trade is brisk. Steel foundries are moderately busy. Steel scrap supplies are more abundant at a price approximating 10*l.* per ton. Pig-iron supplies are coming through steadily, although not in quantities sufficient to leave a margin for stocks. A feature of the trade in raw and semi-finished materials is the increased supply of American soft billets that are coming into the district at 22*l.* per ton, representing a saving of 1*l.* 10*s.* per ton on the reduced official quotation for local billets of this class.

South Yorkshire Coal Trade.—Supplies coming forward during the past ten days have been greatly deficient in tonnage. Iron and steel works have been compelled to make further inroads into small emergency stocks to keep plants running. Hence, if a strike occurs, many more of the principal works will be compelled to close down immediately. Railway companies are again taking large quantities of hard steams. Cobbles, nuts and slacks are all keenly pressed for on contract account. The tonnage available for open market disposal is confined to inferior qualities. Pressure in the house-coal section is not so great as a week ago, but normal conditions have not yet been restored. The shortage of coke is one of the chief causes of restricted production in the pig-iron trade. Quotations :—Best branch hand-picked, 37*s.* 2*d.* to 38*s.* 2*d.*; Barnsley best Silkstone, 37*s.* 2*d.* to 37*s.* 8*d.*; Derbyshire best brights, 35*s.* 2*d.* to 36*s.* 2*d.*; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.*; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.*; Yorkshire hards 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; rough slacks, 28*s.* 2*d.* to 29*s.* 2*d.*; nutty, 27*s.* 2*d.* to 28*s.* 2*d.*; smalls, 23*s.* 2*d.* to 24*s.* 2*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is very little business passing in Cleveland pig-iron just now. Foundry kind continues markedly scarce, and as yet none can be spared for sale to customers abroad, but silicious iron is being sold on export account at 277*s.* 6*d.*; and mottled and white, which are fairly plentiful, are being offered freely at 247*s.* 6*d.* for despatch to foreign ports. For home purposes, No. 1 remains at 237*s.* 6*d.* and No. 3, as well as the commoner kinds of Cleveland pig-iron, stands at 225*s.* Producers are very disinclined to make any concessions on home sales of mottled and white.

Hematite Iron.—There is not much hematite iron on the market. Makers have none to offer, having sold their output over the next few months, and at the moment second-hands have not a great deal to dispose of, though they have large quantities to take up. No. 1, 2 and 3 East Coast brands are 260*s.* and No. 1 is 262*s.* 6*d.* for home consumption. For shipment to France, Belgium and Italy, mixed Nos. are 265*s.* and No. 1 is 267*s.* 6*d.*; and for dispatch to other foreign destinations 280*s.* and upward has been paid for mixed Nos.

Foreign Ore.—Foreign ore is idle, but renewal of activity is looked for as consumers are giving much more consideration to offers, and sellers are keen to make contracts. Rubio, of 50 per cent. quality, is 47*s.* 6*d.* ex-ship Tees.

Coke.—Nothing new of moment is noticeable as regards coke. Supply falls a good deal below what could be wished, and indeed deliveries to some of the local blast furnaces are barely sufficient to satisfy absolute requirements. Average furnace kind is 62*s.* 9*d.* at the ovens, and quality low in phosphorus is 65*s.* 3*d.* at the ovens. Coke is practically unpurchasable for export.

Manufactured Iron and Steel.—There is little or nothing passing in finished iron and steel, and the opinion is gaining ground that to induce buying substantial reductions in prices will have to be made, for America and Belgium are beating us in markets abroad, and are even competing successfully for home trade. American billets have arrived here, and other cargoes from the States are reported to be due in the very near future. The following are among the principal market quotations :—Common iron bars, 30*l.*; marked bars, 32*l.*; iron angles, 30*l.* 15*s.*; channels and flats, 24*l.* 5*s.*; rounds and squares, 26*l.* 10*s.*; steel ship, bridge and tank plates, 24*l.* 10*s.*; steel angles, 24*l.*; steel boiler plates, 31*l.*; steel joists, 24*l.*; soft steel billets, 23*l.* 10*s.*; heavy steel rails, 25*l.*; fish plates, 30*l.*; black sheets, 36*l.* 10*s.*; and corrugated galvanised sheets, 42*l.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The labour position has driven the arrangement of new business to an almost complete standstill. On the one hand the quantity of coal available for shipment to home bunkering ports is insufficient to meet shippers' requirements, and on the other the stringency of the authorities in respect to releases for export are so tight that it is almost a matter of impossibility to carry through transactions. A week ago there was a confident feeling that a strike would be averted, but recent events have changed ideas, and it is generally anticipated that a stoppage is inevitable. In any case, should the threatened national strike be averted, it is believed that sectional stoppages are practically certain, and this would of course considerably reduce outputs, which are already insufficient to meet home and foreign requirements, and thus diminish the quantity available for shipment. The difficulties of operators generally are further aggravated by the fact that collieries are now banking a proportion of current outputs for their own use in view of possible eventualities. Again, the majority of collieries are in arrears with contract commitments, and the home demand is so pressing that in nearly all cases they have nothing for disposal on the open market, and prices are nominally firm at 115*s.* for large, 107*s.* 6*d.* throughs and 95*s.* smalls. The August f.o.b. price for large coal shipped at Cardiff, including contract prices, worked out at 91*s.* 6*d.* per ton, compared with 75*s.* 9*d.* in January, at Newport 98*s.* 4*d.* against 68*s.* 5*d.*, at Swansea 88*s.* 2*d.* against 68*s.*, and at Port Talbot 83*s.* 6*d.* against 80*s.* 11*d.*, while for smalls shipped at Cardiff the average was 75*s.* 4*d.* against 59*s.* 4*d.* in January, at Newport 80*s.* 3*d.* against 48*s.* 2*d.*, at Swansea 52*s.* 4*d.* against 42*s.* 10*d.*, and at Port Talbot 56*s.* 9*d.* against 48*s.* 9*d.* Foreign coal exports from South Wales in the past week, at 208,598 tons, were 46,000 tons less than in the previous week. Of the total only 83,000 tons went to France, 42,000 tons to Italy, 6,000 tons to Spain, 21,000 tons to Portugal, 49,000 tons to British coaling depots, and 8,000 tons to "other countries." There is an urgent demand for bunkers for ships' own use, and with supplies scarce owners are ready to pay a premium of from 2*s.* 6*d.* to 10*s.* per ton on the fixed colliery prices for the oddments which middlemen have for disposal. There is no doubt that of late a considerable quantity of shipping has been diverted from South Wales, for there are now not any vessels in the Mumbles Roads and only 11 in the Barry Roads, waiting to enter the local docks, compared with an average of about 50 during the past month. Coke and patent fuel are practically out of the market, and for the former the nominal price is round 260*s.* per ton and the latter 150*s.*, with business practically at a standstill in the absence of supplies.

STEAM POWER PLANT AT NIAGARA FALLS.—We learn from our American contemporary, *The Electrical Review*, of Chicago, that on account of the high cost of labour and material, the Hydro-Electric Power Commission of Ontario has decided to postpone indefinitely the construction of the proposed auxiliary steam power plant in the Niagara Falls district. The tenders submitted indicated that the total cost of the initial 50,000-h.p. unit would amount to over 5,500,000 dols., instead of about 4,000,000 dols. as was anticipated, and, moreover, the earliest deliveries guaranteed were such that the plant could not have been put into operation before the end of next year. It was also estimated that the high cost of installation and operation, together with the price of coal, would entail an additional cost of 10 dols. per horse-power for power in the Niagara district.

BRADFORD TECHNICAL COLLEGE.—We have received a copy of the Calendar of this college giving full particulars of the courses of instruction in the various departments. Full-time day courses and part-time (mainly evening) courses are provided in textile subjects, including dyeing, chemistry, mechanical engineering, civil engineering, electrical engineering, and other subjects. The courses have been specially designed to meet the needs of students wishing to receive a technological training which will enable them to occupy the higher positions in industry. The full-time courses in the college are of university standard, and candidates for admission to these courses, who have not passed the matriculation examination, or one of its equivalent examinations, are required to pass the college entrance examination. The part-time courses in the college are intended to meet the needs of those students who are engaged in industry during the greater part of their time. These courses form a large and important part of the work of the college. In addition to the organised courses, the college provides special facilities for those students who may wish to undertake advanced study. Students may also undertake research work, for which purpose additional equipment and accommodation is being provided. The equipment of the college includes a complete plant for the washing, carding, combing, spinning, weaving, dyeing and finishing of textiles, and the power house which supplies the whole of the power and light required by the college has been arranged for demonstration purposes. The Engineering Department includes special mechanics, testing, heat engine, motor car and electrical laboratories.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, October 1, at 8 p.m., at Caxton Hall, Victoria-street, S.W., "Notes on Factory Management," by Mr. H. Neville Munro, Member.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—Friday, October 1, at 11 a.m., meet at the Beckton Works of the Gas Light and Coke Company. Paper by Mr. F. W. Goodenough, "Gas in Relation to the Housing Problem." Discussion. 1.15 p.m., luncheon by kind invitation of the Governor and Directors of the Gas Light and Coke Company. 2.30, inspection of works.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—Saturday, October 2, at Bury St. Edmunds, Eastern Sub-District Meeting. Members will meet at the station at about 11 a.m., and will have an opportunity of inspecting the various public works and departments of the borough. At 2.30 p.m., at the Town Hall, the members will be welcomed by Mayor Alderman T. H. Nice, J.P., and a paper by Mr. W. I. Tait on the "Public Works of Bury St. Edmunds" will be read and discussed. The South-Western District Meeting will take place on the same day at Tiverton, members meeting at the Town Hall at 1.30 p.m. At 3 p.m. a reception will be held by the Mayor and a paper by Mr. J. Siddalls, on "Housing," will be read and discussed.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The conditions in the Scotch steel trade are practically without change this week, but the unsettled state of the labour market is having its effect on the industry by causing buyers to hold off. Inquiries are not numerous, and although orders on hand will keep the mills all running steadily for some time the future has to be considered, and little forward business is being fixed up. For ship and boiler plates there is a steady demand, and this is likely to continue for a few months, but unless the position alters considerably in the matter of prices, forward bookings will not be very heavy. For sectional material the demand is still easier, and producers are seeking fresh business, and for which they can promise early delivery. Makers of black sheets are fully employed, but orders against contract for the lighter gauges are not quite so pressing. Bookings will carry the works well on towards the end of this year. Galvanised sheets which have been doing fairly well recently are a shade easier, and the demand has slackened off, although a few respectable inquiries are in the market this week. Steel material all round shows an easier tendency, but the export trade has not appreciably opened out yet.

Malleable Iron Trade.—The malleable iron makers in the West of Scotland continue to be very busy, and with a large output, but many consumers are not so urgent in their demands at the moment. Fresh business is not being booked to any great extent and new lines do not amount to a very heavy tonnage despite the fact that fairly good delivery can be promised. Prices are steady, but respectable contracts can be placed on favourable conditions.

Scotch Pig-Iron Trade.—The Scotch pig-iron market rules steady, but the uncertainty with regard to the possibility of a strike in the coal trade is being reflected in the iron trade. There is nevertheless a very constant demand for foundry iron and hematite, and the scarcity of these still continues. The home consumers are all active buyers, but a little more is being exported abroad. Steelmakers are getting through large quantities of hematite, and all that is available is being secured against contract. Prices continue very firm, and with the output of pig-iron so much under what it should be there would seem to be no immediate necessity of reducing quotations. If the miners' strike is averted and the import of iron ore continues to improve, there will be a much larger amount of iron available in the near future and the present shortage will be overcome. Overseas buyers are keen for deliveries, but the pressing demands of the home trade are being met firstly, and only a small percentage is being exported.

The State of Trade.—Active conditions are still general in the shipbuilding and engineering industries throughout the country and only the shortage of supplies of iron and steel material are keeping things back a bit. There is a large amount of work booked by most of the engineering firms and provided that labour difficulties of one sort and another do not arise to cause trouble, the remaining months of this year should see a very large output. Makers of rivets, bolts and nuts, as well as tubemakers and nailmakers, are all well employed, and order books are so satisfactory that the outlook for the next few months is very good indeed. This is provided that there is no general stoppage caused by the non-settlement of the many labour troubles which are at present darkening the horizon.

COAL IN THE MALAY PENINSULA.—Last year's output of coal from the Malayan collieries in the State of Selangor, Malay Peninsula, amounted to 191,293 tons, as compared with 168,740 tons in the previous year and 155,279 tons in 1917. The natural increase of output was prevented in 1918 by difficulty in obtaining machinery and plant and by shortage of labour. The latter difficulty also gave trouble during the year under review, but the increase in output may be regarded as distinctly satisfactory in the circumstances, and the management expect ultimately to attain an annual output of 400,000 tons.

H.M. ARMOURED CRUISER "RALEIGH."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LIMITED, ENGINEERS AND SHIPBUILDERS, DALMUIR.

(*For Description, see Page* 418.)

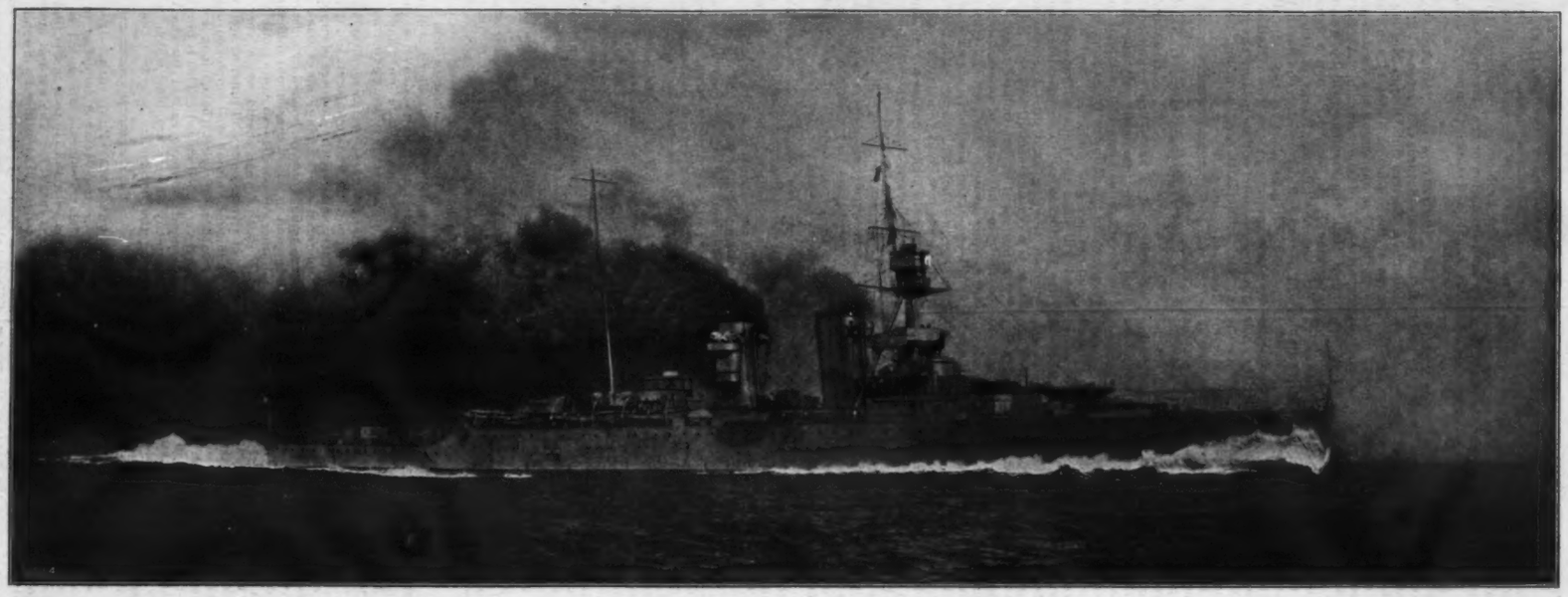
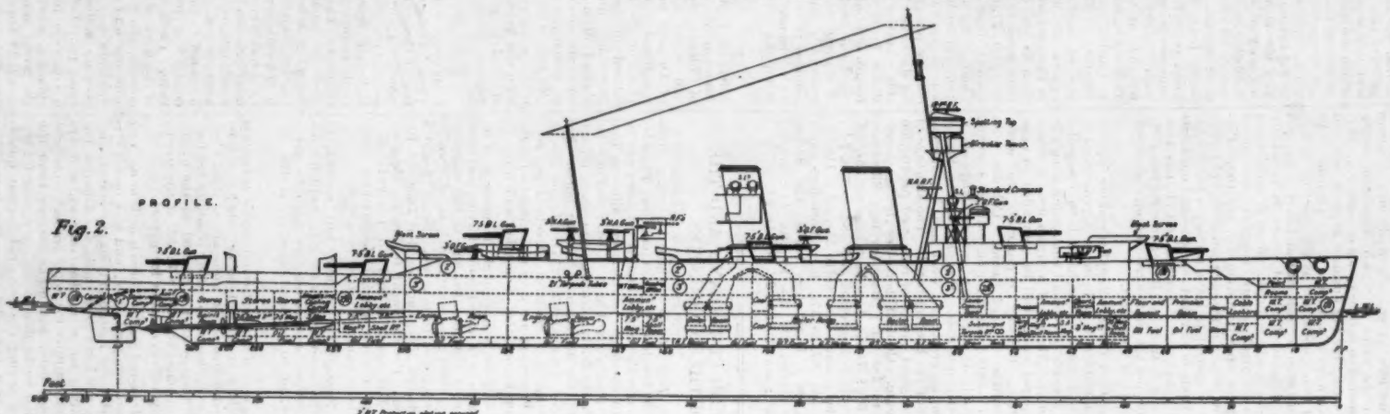


FIG. 1. VIEW OF THE VESSEL ON THE MEASURED MILE.

Fig. 2.

PROFILE.



FORECASTLE & UPPER DECKS.

Fig. 3.

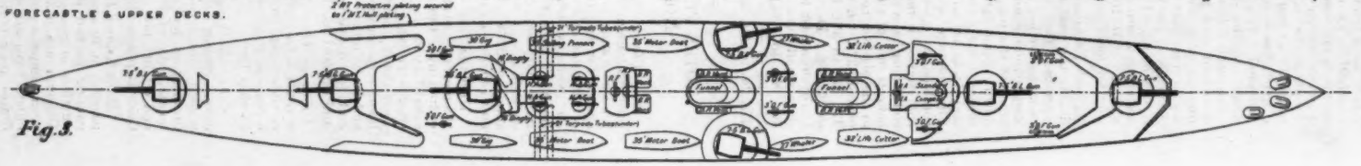
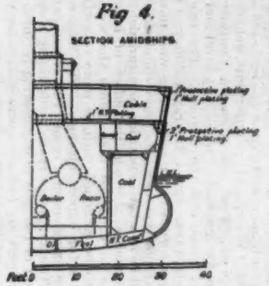


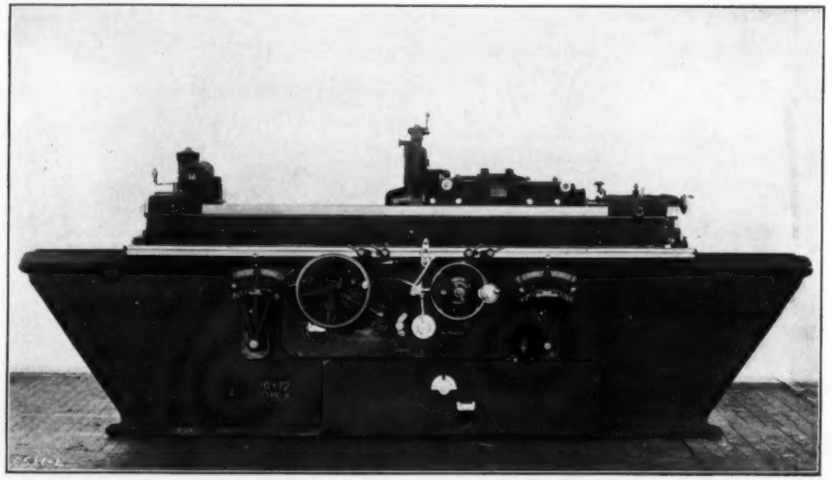
Fig 4.

SECTION AMIDSHIPS.

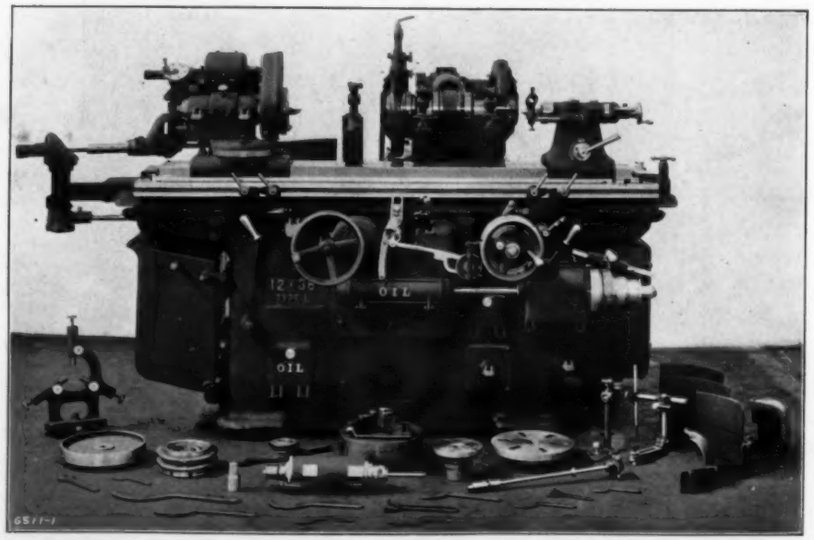


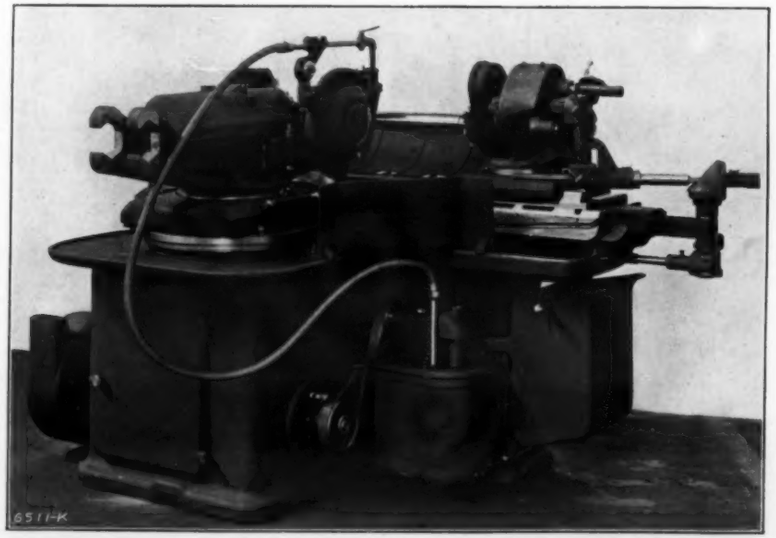
THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 397.)



FIGS. 168 AND 169. 36-IN. UNIVERSAL GRINDING MACHINE; MESSRS THE NORTON COMPANY.





FIGS. 166 AND 167. 72-IN. CYLINDRICAL GRINDING MACHINE; MESSRS. THE NORTON COMPANY.

(*To face page* 398.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA

(*For Description, see Page* 397.)

Fig. 170.

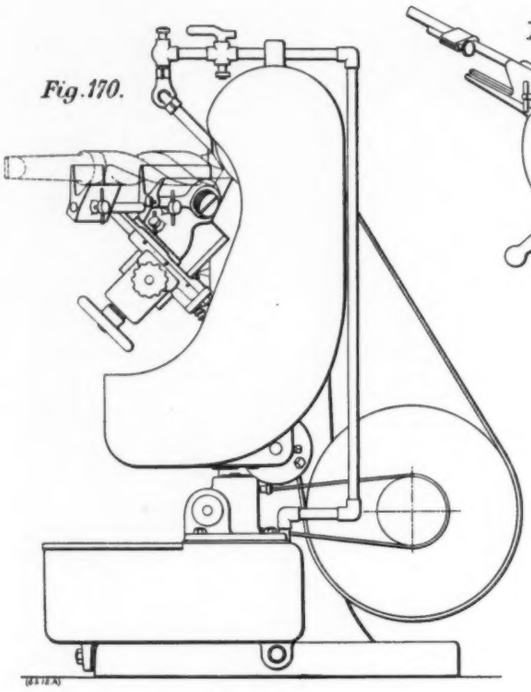
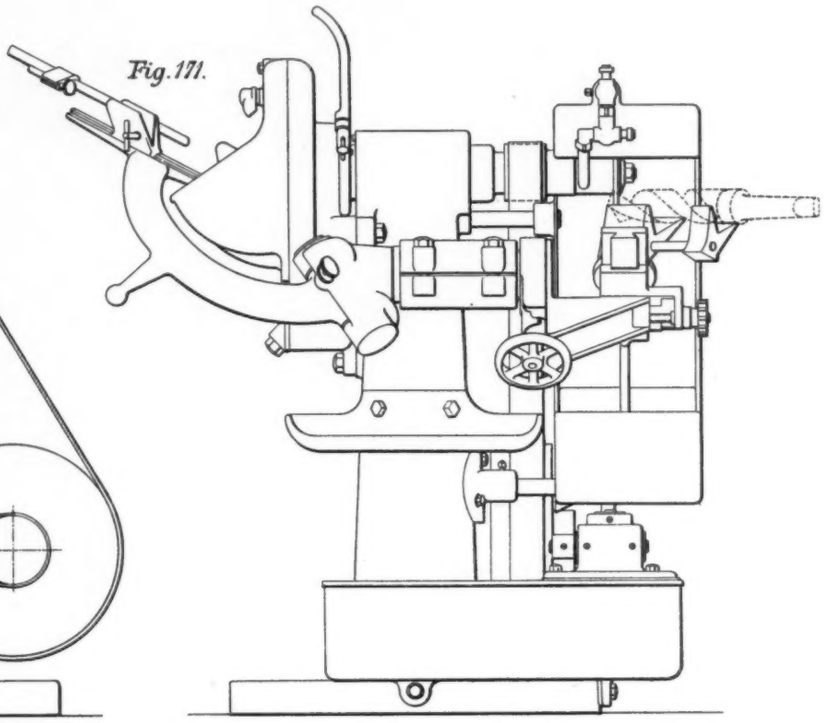


Fig. 171.



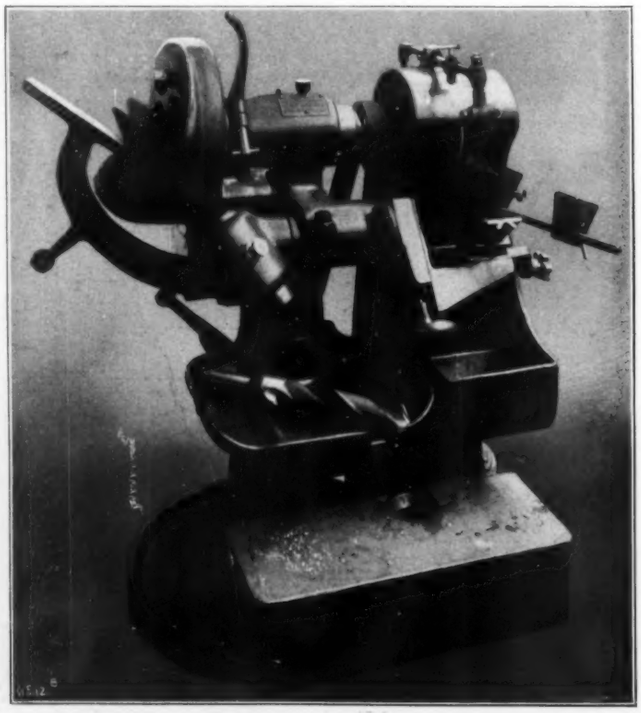


FIG. 172.

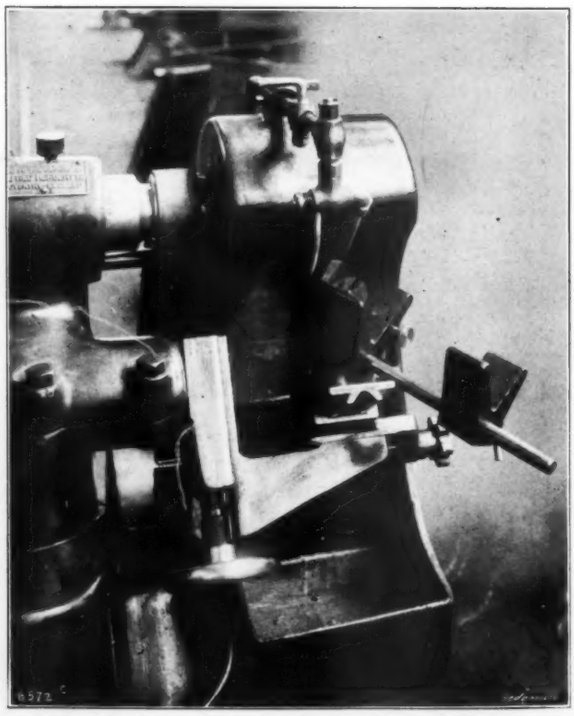


FIG. 173.

FIGS. 170 TO 173. BALL BEARING TWIST DRILL GRINDER; MESSRS. ALFRED HERBERT, LIMITED.

(*To face page* 399.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 397.)

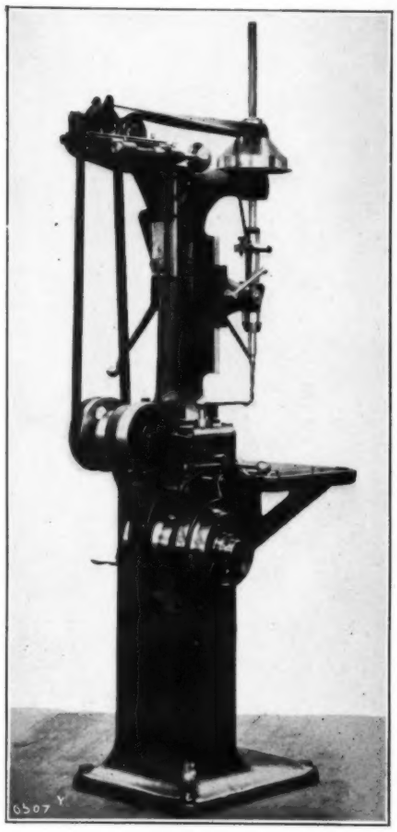
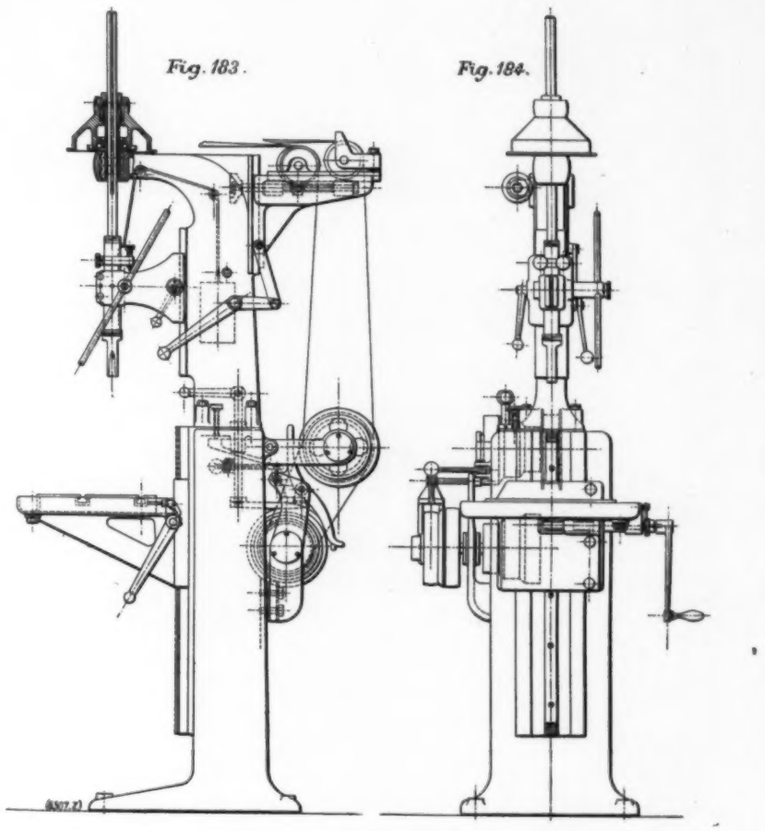


FIG. 182.



FIGS. 182 TO 184. HIGH-SPEED SENSITIVE DRILL; MESSRS. B.S.A. TOOLS, LIMITED.

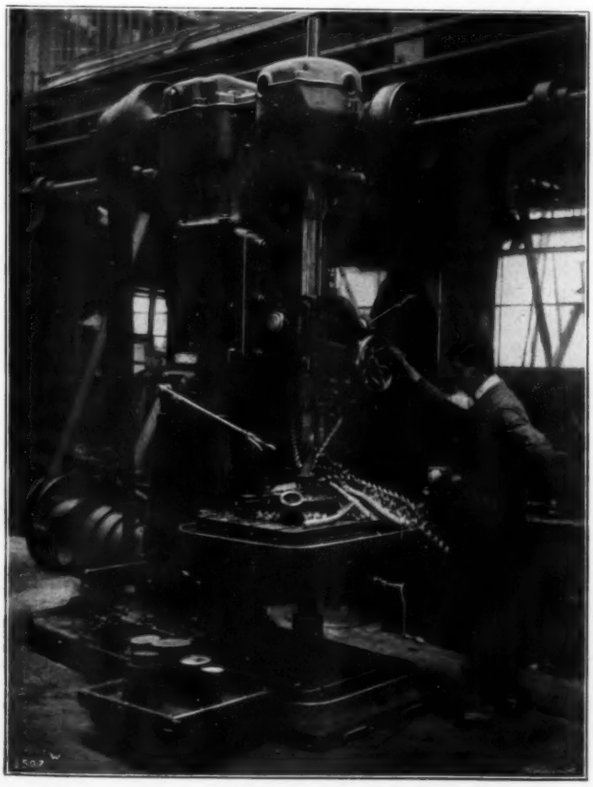


FIG. 185. 30-IN. UPRIGHT DRILL; MESSRS. A. A. JONES & SHIPMAN, LTD.

FIG. 186. HEAD AND FEED-BOX OF JONES AND SHIPMAN 30-IN. DRILL.

(*To face page* 400.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 397.)

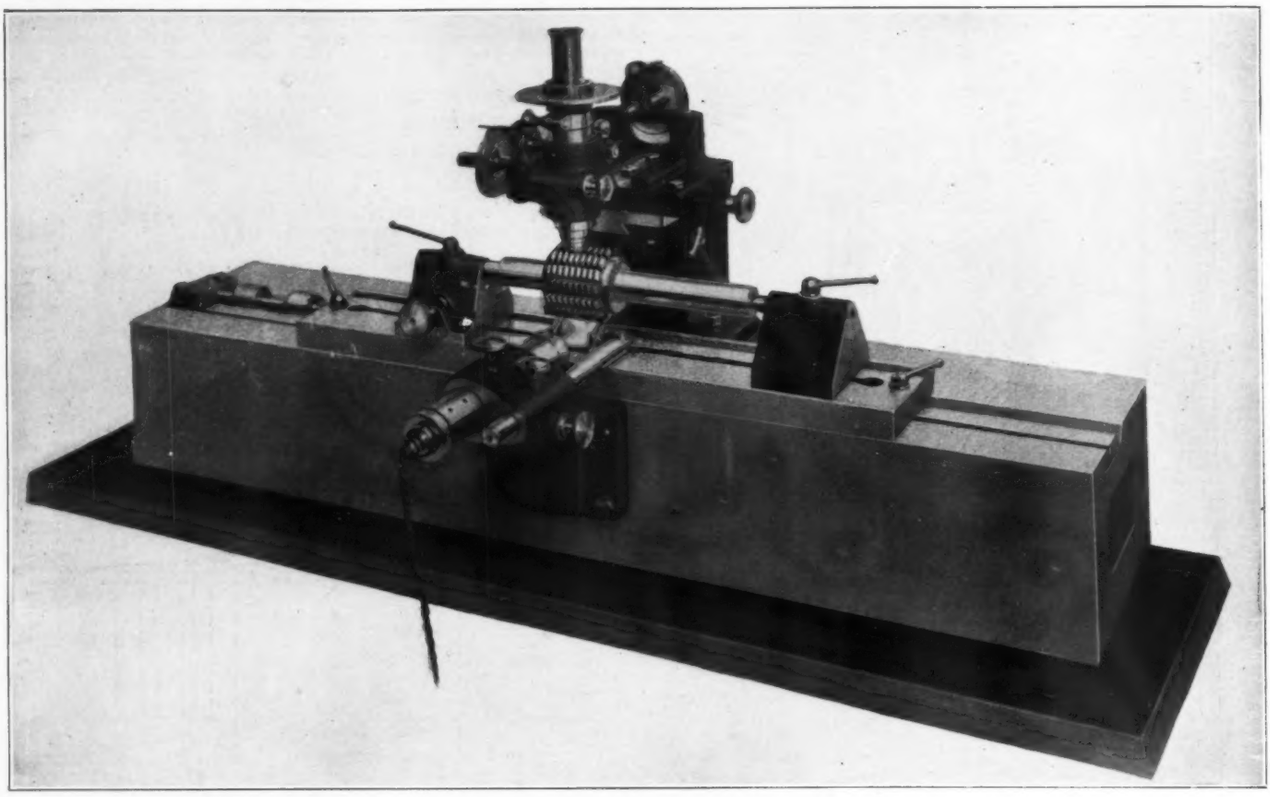
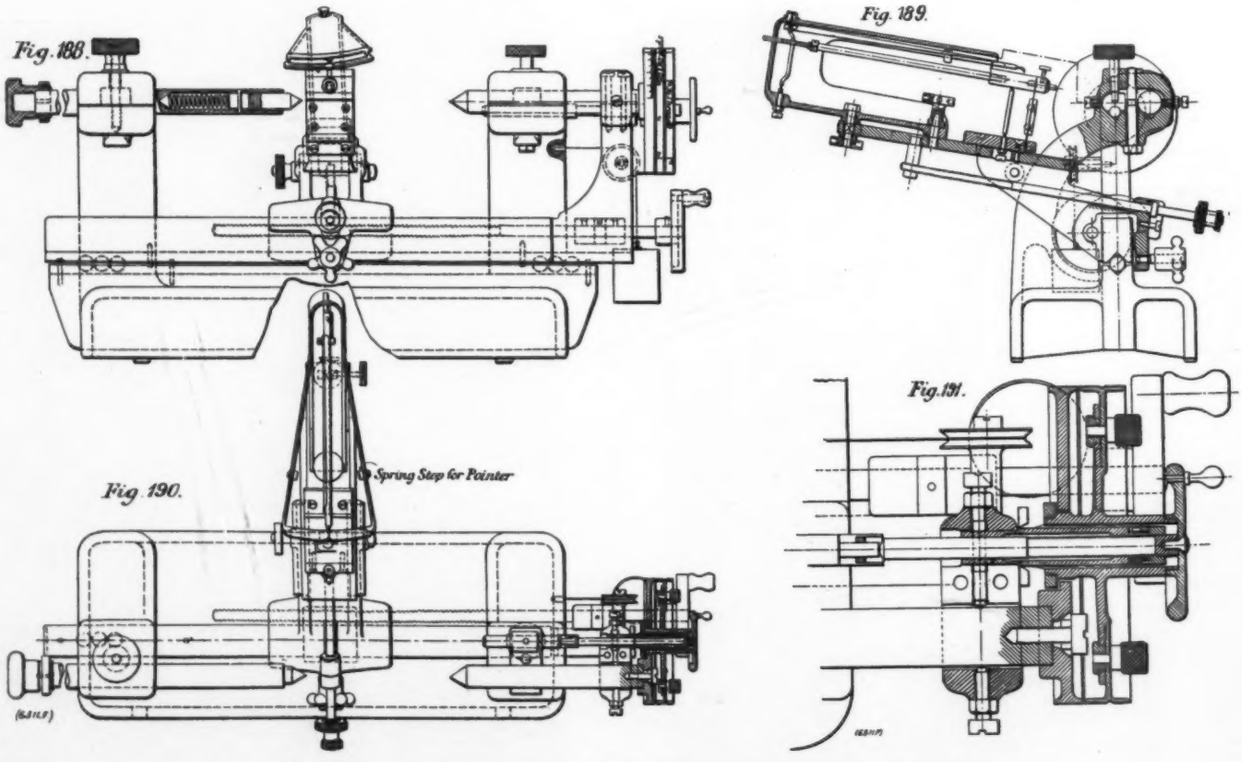


FIG. 187. MICROSCOPIC MEASURING MACHINE; MESSRS. ALFRED HERBERT, LIMITED.



FIGS. 188 TO 191. PITCH MEASURING MACHINE; THE TECHNICAL COLLEGE, LOUGHBOROUGH.

(*To face page* 401.)

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AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Angus and Robertson, Limited, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
BELGIUM, Brussels: E. F. Satchell, 86, Rue du Tabellion.
CANADA, Toronto, Ont.: Wm. Dawson and Sons, Manning Chambers.
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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. As the postal rates have been again increased, the price of single copies sent by inland post is now 1s. 2½d.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 409.

ENGINEERING.

FRIDAY, SEPTEMBER 24, 1920.

OUTPUT.

THE incidents of the past week have thrown a curious light upon the place which output is given in the economic world as pictured by part of the community. Amid all the social tribulations which harass the world to-day, the bulk of the people seem to be in danger of forgetting that production is the very key of our existence, and prefer to put wages first at all cost, production problems being of quite secondary importance to them. If, on the other hand, we talk of the producer being the only useful member of society, Labour cheers to the echo, claiming for itself that as an unique characteristic, an attitude which of course arises from shortsightedness. While refraining from the now somewhat hackneyed reference to the brain worker, let us consider a class very often drawn from among the so-called "workers." The salesman is not strictly a producer. He ranges in dignity through all sorts of grades from the humblest shop assistant to men occupying positions of high responsibility and remuneration. He has no pile of material products to show as the result of his handiwork, yet he is none the less a most essential member of society, as the working classes in Italy have recently discovered. In the late developments there though the factories continued to produce while in the hands of the workers, without sales they soon found their products valueless. So, apart from the actual hands which hold the hammer or file, the trowel, or whatever implement a trade requires, there are thousands who fit into proper niches or go to form the correct number of teeth in our national wheel of progress without whom the machine would stop. A trade is no use without the means of trading with other people—a fact we grow daily in more need of remembering with all the nonsense that is now parading as economic doctrine, and any creed which aims at making all other sections of the community subservient to the manual worker is necessarily unsound.

Of course, wages and output are actually very closely allied, in order that we may trade successfully. Trading with other people involves at least three fundamentals: Firstly, that we can produce something wanted by somebody else; secondly, that we can organise selling; and thirdly, that the commodity we produce can be sold at a price at which other people can buy, without loss to ourselves. We can dismiss the second point briefly as it is obvious. It is useless manufacturing here something which would sell, say, in Japan, and from which country we, in return, could get something useful to us, if the means of letting the fact be known there, and of sending the product to that country, be non-existent. Selling organisation is therefore essential to the producers.

On the first point there is not only no doubt that we as a nation can produce goods of a quality which will command a sale, but behind this is the fact that we simply must produce on a large scale to support our population in so small a country. It was the enthusiastic production at home which carried our men to victory in the recent war. Without it all the sacrifice of valiant lives would have been in vain. For long years we have failed to be self-supporting and have had to obtain our necessities from people abroad who in their turn wanted something we could make and they could not. This is our only means of obtaining food, and such trade is more vital to the country now than ever, in order to reduce our indebtedness to other countries. If we fail in this production we pile up debts against us till our credit will fail and foreign countries will refuse to sell to us. Of what avail then will it be that our workmen are the highest paid and work the shortest hours of any in Europe?

Naturally, to complete the transaction of selling there must be a buyer, and we can only maintain or redress our balance by producing at a price at which others can afford to buy, and buy largely. It is doubtful whether any consideration at all is given to this point by the bulk of the men who ballot so recklessly for strikes on the advice of a few extremists. It is impossible to think that anyone can honestly believe that the working or any other classes stand to benefit in the long run by the constant suspense and uncertainty with increasingly frequent intervals of interruption from which industry is suffering to-day. How can production be cheap under such conditions? Take one point alone. Overhead charges have to be spread over a reduced productive time, and with the general tendency to reduce also individual output, costs are bound to rise. Ultimately trade will decline. Again people have the habit of making a comparison of their living with that of other classes, their sole guide for wages demands, regardless of the value of their performances. The result is fictitious wage scales which industry may stand for a time, but which will certainly react against us in our dealings with other countries, and therefore in the purchase of the necessaries of life. These are certainly not the ways to reduce the costs of our products and increase our sales. A shrinkage in demand will follow, and then—unemployment.

The busy time of reconstruction has afforded a large amount of work at home, and advantage has been taken of the war, and post-war conditions to improve considerably the standard of the workers. There is a danger of the movement being carried further than is wise, if it has not gone that far already, to our national disaster. Speaking at a meeting of the Industrial League and Council held on Tuesday last, at Olympia, Mr. G. N. Barnes laid great stress upon the near relationship of production and employment. He stated that modern methods had reduced unemployment as a whole. Analysing figures for long periods he had come to the conclusion that with the development of science engineering unemployment had been less in this century than in previous periods. He argued for the best machinery, and for good organisation in order to decrease production costs. With large production, and reduced costs, commodities are brought within reach of a wider range of society. Take an instance which, however, we do not draw from the necessaries of life. The gramaphone as we know it to-day is a modern factory production. The cost of the instrument has been so reduced that a machine of fair quality has been brought within the spending capacity of thousands of working-class homes. This fact, of course, is now responsible for the employment of a large number of hands in this particular industry which did not exist a few years ago. Employment has been to that extent improved. It is true that the example is taken from what some consider to be a luxury; whether so or not this particular product has so invaded the home of the workers that it may be regarded as contributory to that "standard of living" of which we hear so much to-day.

The case is similar with articles which we trade for the necessaries of life. The more reasonable we can make our price by adopting the most approved methods the greater our benefit, as we shall be able to trade with more people. As a matter of fact, just now there would be purchasers

enough in all conscience if conditions were more stable and prices reasonable. With the leeway of five years' wastage to make good on the Continent, to say nothing of needs at home, there is no doubt that if we could cut down our costs and make something like definite promises we would have work for months if not years to come. In a few remarks by Sir Alfred Herbert at Tuesday's meeting he stated that what was most essential at the present time was industrial peace and stability of prices and delivery. But we enjoy neither under the agitation maintained by a comparatively small but violent section of the nation, with the result that these constant upheavals are curtailing our output, enhancing our producing costs and carrying our balance with other nations from bad to worse. The general opinion is that buyers are holding off, owing to the uncertainty of the next few months. Is it surprising? Yet without buyers there can be no employment. The threatened coal stoppage will not only cost our country directly much hardship and loss in contingent industries, owing to the loss of wages, but it will throw us still further out with other countries since coal is one of the products we can still advantageously trade abroad. And this, strangely enough, is what the miners' leaders call an unselfish movement primarily for the general benefit of the community. The mental obliquity thus evinced is certainly astonishing.

But Mr. Barnes quite rightly coupled with his plea for good machinery and organisation, a third point, which was the active co-operation of the live human factor. Here is where we fail to-day—this co-operation is unfortunately lacking. The miners' leaders have offered increased production, but as has been pointed out to them we have had this promise before, but no result. In other trades there has been much talk about increase, but nothing to show, while payment by results has been definitely turned down by some. Could we bridge these gaps our future would be assured, and it behoves the leaders of the moderate men who still form the mass of our workers, to bring all the restraining influence they can to bear upon the present movement, to reduce order out of chaos in time to prevent us being swept into the misery which the extremists seem to regard as the highest possible ideal.

WATER POWER IN BRITISH GUIANA.

THE fuel situation in this and many other countries has given hydro-electric development a new attraction. Even in the British Isles we have been led to close inquiry into the possibilities in this direction, while in many of the countries of the Continent the present fuel stringency has added new impetus to a form of development already well advanced. There are many parts of the world, however, in which the utilisation of natural water power has been and must be looked upon more from the point of view of the general development of the country than from that of fuel saving, since no important quantity of fuel is, or ever has been, used there. British Guiana is, we think, a country which very clearly comes within this class. This comparatively little-known part of the Empire is practically undeveloped, except in the neighbourhood of the coast, but the natural possibilities are considerable, and an adequate supply of reasonably cheap power might lead to valuable trade issues.

Doubtless, actuated by ideas of this kind, the Governor of British Guiana, in March of last year, arranged with a civil engineer, Mr. Stafford X. Comber, for a preliminary survey of the water resources of the country, particularly those susceptible of hydro-electric development, and within the zone of practical power transmission to the existing industries on the coastal belt. In making a case for the expenditure of considerable capital on any actual power scheme, it is clearly desirable that all possible data should be collected relating to existing power consumption, and Mr. Comber circularised all important power consumers in the Colony on this point. The replies were apparently very disappointing, and no complete information was collected in this way. From the information which was received, however, coupled with a use of existing statistics and other matter, it is estimated that the present maximum power consumption is in the neighbourhood of 30,000 h.p. This does not include power spent in the form of lighting, so that, assuming any considerable portion of the existing load could be obtained, a case for at least some form of hydro-electric development would appear to be made.

There was, and we believe, there still is, in existence, a Parliamentary Committee on the Economic Development of the Colonies, and when this Committee comes to consider the case of British Guiana, its vision will naturally extend further than the meeting of the existing power demand from water sources; the possibilities of the future must occupy a large part in any consideration of what hydro-electric development can do for the country. The existing industries of British Guiana are largely concerned with the production of sugar and rice, and the former industry in particular, is stated to be hampered by shortage of labour. The electric drive should not only lead to an extension of the sugar industry, but should enable it to be carried on more economically. The labour cost in a sugar factory ranges from 4 per cent. of the total cost of the sugar in Hawaii, to 10 per cent. in Cuba, and a detailed study of a steam-driven producing plant showed that by labour-saving and in other ways, a change-over to the electric drive would materially reduce manufacturing costs. Twenty-six men could be dispensed with in a factory producing 1,100 bags of 325 lbs. each per day. There are many other ways in which a supply of electric power would assist the Colony. Apart from supply to the larger towns, there is now considerable expenditure of fuel in connection with drainage work, and it is suggested that paper and fertilizer works might be introduced. The Colony now spends a million and a quarter dollars a year on these items. It is not difficult to suggest other ways in which abundance of power would help the country and obvious considerations arise in connection with transport and the handling of material.

The report which Mr. Comber has prepared is of a preliminary nature only, which one will realise must be the case when it is stated that his survey extended only to 30 days and covered the examination of three important rivers. Much valuable information was, however, collected, and suggestions were made in connection with further detailed examination, and the collection of meterological records, which should be of great value when the matter is further dealt with. Mr. Comber appears to have been but slenderly equipped for his expedition, and in view of the fact that from the point of view with which he was concerned, he was dealing with virgin territory, the amount of information he collected is remarkable. The report should form a valuable basis for development in the future under Government or any other auspices.

The rivers which were examined were the Cuyuni, the Essequebo and the Demerara. The latter of these is the best known, both by name and in actuality. The name has got itself connected with the staple product of the Colony, while actually the river is that of greatest commercial importance in the country, being navigable by ocean-going steamers some 65 miles from the sea, and a regular launch service being maintained for a distance of 45 miles further inland. The river, however, is actually the smallest of the great rivers of the Colony. The Essequebo is the greatest river of the country, and flows for 600 miles entirely in British Guiana. It has a delta 10 miles wide. In size the Cuyuni lies between the Demerara and the Essequebo, and like the latter, is much broken up by rapids and falls. At points selected for measurement, Mr. Comber estimates the flow of the Cuyuni at from 39,000 cub. ft. to 93,000 cub. ft. a second, that of the Essequebo at from 68,000 cub. ft. to 250,000 cub. ft. a second, and that of the Demerara at from 1,200 cub. ft. to 5,000 cub. ft. at the Great Falls, and from 1,700 cub. ft. to 6,500 cub. ft. at another site.

The question of the cost of transporting materials to any sites selected for water-power works, is an important one, but Mr. Comber states that for the positions he proposes on the various rivers, there would not be much to choose between them from this point of view. He makes recommendations for each river, but points out that questions of storage accommodation could not be properly determined without more detailed surveys than he was able to make. On a conservative estimate, however, he is of opinion that a 24-hour load of 285,000 h.p. could be obtained from the Cuyuni River, one of 475,000 h.p. from the Essequebo, and one of 38,000 h.p. from the Demerara. Allowing 20 per cent. turbine loss, 10 per cent. gearing loss, and 8 per cent. generator loss, and also 10 per cent. in transmission and 4 per cent. in each of the transformations, he estimates that 156,000 h.p. could be obtained from the Cuyuni, 273,000 h.p. from the Essequebo, and 21,000 h.p. from the Demerara, and delivered to customers within 200 miles radius. This would cover all present industries in the coastal belt.

PROLONGED LETTERS PATENT.

CERTAIN alterations have been made recently in the law relating to the extension of the term of Letters Patent, and there have now been published three very important decisions showing the practice which is likely to prevail in the Courts under the present law. These will be of interest to a large number of patentees in view of the fact that many summonses have been taken out for extension of term under the new Act.

The Patents Act of 1907 provided that a patent might be extended on a petition to the Court. The procedure was costly, and cases were scrutinised very carefully. The petition had to be presented at least six months before the expiry of the patent, and in practice it had to be presented not very long before the six months, so that the Court would be in a position to judge all of the profits which were likely to be obtained before the end of the term of the patent. The new Act of 1919 introduced an additional section providing that where by reason of hostilities the patentee as such suffered loss or damage, application may be made by way of a summons. Thus the procedure in this section has been simplified, and the point to be noticed is that the Court in considering its decision may have regard solely to the loss or damage so suffered by the patentee.

The three cases to which reference has been made above were applied for under this section. In the first—Brown's patent relating to dredgers—the patent had expired more than three years before the application for extension was made. In the second and third case, relating respectively to Davidson's patents on the coagulation of india-rubber and Gaskin's patents for life-saving rafts, the patents had several years of their terms unexpired.

In Brown's case, the patentee with his family owned almost the whole of the capital in a company which manufactured vessels of the order of about one per annum until 1915. After that the company was controlled and no dredgers built. Here it was held, first that the patentee was claiming in respect of a loss sustained by him, not as patentee, but as a shareholder in the company, and that the company had only suffered in common with other shipbuilding companies and not as a result of the patent position. It was also held that without deciding that it was impossible to grant an extension of a patent when the patent had expired for three years before the application it would have to be a very special case indeed for the grant to be made. In this particular case the judge thought that no special case had been put forward.

In both the Davidson and Gaskin cases the applicants alleged that by reason of hostilities they had been unable to begin to work the patented inventions. They contended that the sole reason for requiring petitions to be presented shortly before the expiration of patents was that the Court might be in a position to judge of the adequacy of the remuneration received, and that under the section in question in the new law inadequacy was not material. They contended that the word "may" referred to above (the Court . . . may have regard solely to the loss . . .) ought to be read as "shall," and that it would be more easy to prove loss shortly after it had occurred than at a later period. The Comptroller took the adverse view, and this was subsequently affirmed by the

learned judge. He held that except in so far as alterations were expressly introduced in the new law, extensions were intended to be granted on the same general lines as before, and that an extension should be applied for shortly before the expiration of the patent. He did not agree with the contention that the word "may" was equivalent to "shall." He found that the section in question referred to loss or damage during the whole term of the patent, and that it was in general impossible to judge the case properly until a patent had nearly expired.

Some remarks of his judgment may well be noted. He states, "I do not think that a reading of the section of the Act would be justified under which a patentee who thought he was approaching the end of his losses as a patentee and had expectations of recouping the whole or part of his losses should be at liberty to select such a time for his application to the Court as would enable him to prove the maximum amount of loss and obtain the maximum extension of his patent." He appreciates that the question raised will affect a large number of applications pending and prospective, on which it is admitted that there has been some difference of opinion amongst those specially conversant with these matters.

An application was made for leave to appeal in view of the importance of the case. The judge doubted whether he could give leave to appeal which would be an effective leave, but he recognised the importance of the case and said that he desired, if possible, that the applicants should have the opinion of the Court of Appeal. So far as he was able, therefore, he gave the desired leave.

THE IRON AND STEEL INSTITUTE.

THE Iron and Steel Institute held its autumn meeting this year in Cardiff. On the members assembling on Tuesday morning, the 21st inst., in the building of the South Wales Institute of Engineers, they were welcomed by the Right Hon. the Lord Mayor of Cardiff (Councillor G. F. Forsdike), who expressed his pleasure and that of the corporation and the South Wales district as a whole at receiving them. He thought that the district owed so much to the work carried out by the Iron and Steel Institute that if a small part of the debt could be repaid in comfort and pleasure to the members during their stay, he and the corporation would feel gratified. The Lord Mayor also touched upon the present state of unrest, and expressed the fear that if something were not done to cause this unrest to cease, the country would suffer not only in its iron and steel industry, but in all branches of trade. He thought we were still too near the war period and its results to have reached complete safety, and believed the farther we got from the war the closer we should arrive at pre-war conditions, bearing in mind always the effects which the war had left generally. He paid a tribute to the name of a late past president of the Institute, Mr. E. P. Martin, of South Wales, a gentleman whom he always remembered with respect.

Dr. Stead, the president, in the course of a brief reply, said the Institute always had pleasant recollections of their former meeting in Cardiff, in 1897; the present meeting was the first one the Institute had held outside London since the war, and he felt that it would be a most successful one in every respect.

A letter was read from Mr. Edward Windsor Richards, who had been president in the years 1893 to 1895, expressing his regret at his inability to be present, but assuring the members of the lively interest which he still took in the Institute's proceedings. Dr. Stead announced that the sympathy of the meeting would be forwarded to Mr. E. W. Richards, their oldest past president.

The Hon. Treasurer, Mr. I. Williams, then gave notice of a resolution for the alteration of bye-laws 21 and 22; the resolution is to be submitted at the next spring annual meeting in London. These propose that entrance fee shall remain at 2*l.* 2*s.*; the annual subscription for members resident in the United Kingdom shall be 3*l.* 3*s.*; those resident outside the United Kingdom shall pay an annual subscription of 2*l.* 12*s.* 6*d.* A scale is provided in the resolution for compounding subscriptions. Members elected at the autumn meeting will, it is proposed, pay only half the subscription for that year.

THE ELECTRIFICATION OF THE WORKS AND COLLIERIES OF THE EBBW VALE STEEL, IRON AND COAL COMPANY, LIMITED.

The first paper taken at the meeting on Tuesday morning was one having the above title, by Mr. Walter Dixon, who read it in abstract. We publish this paper in full on page 419 of the present issue. This paper was not discussed, Dr. Stead announcing that it was of a character that did not lend itself to discussion. It indicated great progress, and one of its effects would be to lead others to advance still further; it, therefore, marked a step to still further progress.

INTERCRYSTALLINE FRACTURE IN MILD STEEL.

The second paper taken at Tuesday morning's meeting dealt with "Intercrystalline Fracture in Mild Steel." It was by Dr. Rosenhain and Mr. D. Hanson, M.Sc., of the National Physical Laboratory. This paper we print in full in the present issue (*vide* page 421). It was read in abstract by Dr. Rosenhain, who added the remark that the authors had not given in their contribution a theoretical discussion of the phenomena, their object being to call the attention of the engineering world to the points they had brought forward.

Mr. E. H. Saniter, who opened the discussion, suggested that the temperature at which the material had been worked and also corrosion, might have been responsible for intercrystalline fracture in the cases dealt with by the authors.

Mr. C. H. Ridsdale said he had examined many fractures, and had found intercrystalline fractures in over-annealed steels. Other fractures which were right through the crystals were due to cold shearing, the steels being, otherwise, of quite good composition. He had been struck on examining cold sheared billets to find that the cracks invariably were right through the crystals. That would seem to coincide with the authors' observations.

Dr. Hatfield found the paper useful in arriving at a true meaning of the feature it dealt with. There was, however, no evidence in the paper to show that temperature and corrosion did not play some part in the action. Until further evidence to the effect that these two conditions were eliminated, he thought it better to wait before accepting the authors' theory that as a result of a stress exerted over a long period failure might take place below the elastic limit of the material. Since the authors did not enter into the theory of the matter, he (the speaker) would also leave that for the moment. The authors had said that it was not suggested that the phosphorus content of 0·07 per cent. had in any way influenced the intercrystalline fracture in one of their instances. He thought they must have some data on which to base their statement that 0·07 per cent. of phosphorus was not serious, and more interesting information to put forward with respect to all their four specimens. It would also advance the subject if other members having similar cases of fractures would put them before the Institute.

Mr. H. Brearley was glad to see that Dr. Rosenhain began to find exceptions in the cases of fracture, and that some were through the crystals, others being along the boundaries. In ingots there were hundreds of very minute cracks, almost invariably around the primary crystals; these did not weld up, and under stress they opened out and along the lines of the crystals. When mild steel broke after considerable distortion, the crystals were much pulled about and distorted. It was not easy in micro-examinations always to see where the junctions of the crystals were.

Dr. Stead found that Dr. Rosenhain had modified the opinion he firmly held formerly as to the occurrence of fractures. He (Dr. Stead) had studied the question many years ago, and had found that in mild steel there were fractures of two characters, one round the grain and one through it. When a piece of such steel was taken having an intercrystalline fracture, and it was submitted to a sudden shock or pressure, the crack did not continue round the crystals but through them. He welcomed the paper; it gave an idea of the difficulty of the subject. He had also oxidised steel and had found that the oxygen passed between the crystals rather than through them. The inter-granular substance was a most peculiar one; it was not known whether it was amorphous, or was formed of molecules loosely packed.

Mr. D. Hanson, in replying to the discussion, thought that temperature and corrosion might have some effect, and referred back to the paper on these points. It was well known that cold-worked brass in mercury salts cracked in a few minutes. Corrosion, however, was a subsidiary cause. Stress was required to pull the crystals apart, whatever might be the temperature and the corrosion at work. In regard to phosphorus, they (the authors) did not attach undue importance to that impurity; the other samples were low in phosphorus and, therefore, it could not be claimed that the cause was attributable to high phosphorus.

Dr. Rosenhain thought Mr. Brearley was under a misconception when he said he was glad to see him (the speaker) depart from his former emphatic statement as to the occurrence of fractures. When the weakness in steel was at the boundaries, then the crack would pass through the boundaries. In the mild steel the authors had it was easy to distinguish the fractures. The paper described cases of intercrystalline fracture, and did not suggest a departure from former statements to the effect that fractures occurred across or around the structure. The authors hoped one result of their communication would be to lead others to study fractures of the same kind.

THE CONSTITUTION OF THE NICKEL-IRON ALLOYS.

The third paper taken at Tuesday morning's meeting was on "The Constitution of the Nickel-Iron Alloys," by Mr. D. Hanson, M.Sc., and Mrs. H. E. Hanson, of the National Physical Laboratory. After referring to former work on these alloys, the authors detailed their own work, in which special care was taken to prepare alloys free from carbon; their highest carbon was 0·046 per cent. Thermal curves had been taken of all the specimens, and it was only in the alloys containing 30 per cent. to 40 per cent. of nickel that no arrest points had been obtained. From other evidence, it appeared that the temperature at which the change would take place was so low that the reaction was too slow to be registered on an ordinary thermal curve. The alloys were made up of Armco iron and Mond nickel steel; the 21 samples made contained from 1·09 up to 90·71 of nickel, and extreme care was taken in their preparation. The paper gave thermal curves, the electrical conductivity, the heat treatment and microstructures, also an equilibrium diagram. The authors thought the latter to be not far from correct; in any case, they added, the type of the diagram appeared to be definitely established.

The discussion was opened by Dr. F. C. Thompson, who congratulated both the authors and the National Physical Laboratory upon a most valuable contribution. He thought the authors' conclusions as set forth in their equilibrium diagram were amply justified, and were of considerable interest in connection with the work by Osmond and Benedicks, and with the constitution of meteorites. If he might plead one point, it was to state that it was a pity that more complete analyses were not given; complete analyses implied a large amount of work, but in view of the real importance of the conclusions they would form an addition of real value. The composition of the carbon, the manganese content, for example, would be interesting to know; this latter was perhaps quite low, but if information on the point were given it would remove uncertainty. He questioned one statement by the authors in the microstructure section of their paper, to the effect that austenite and martensite were obtained, and the absence of an eutectoid, and thought that one obtained simply ferrite crystals; the small amount of carbon in the specimens might, he considered, have a bearing on that point.

Dr. Hatfield asked whether, seeing that the specimens were heated in a carbon ring furnace, through which purified nitrogen was passed, the nitrogen had any effect upon them. Had they estimated the nitrogen in the alloys?

Mr. J. N. Greenwood asked for further figures

of chemical analyses if it were possible for these to be given. He had worked on similar material, but had to abandon his researches owing to lack of facilities for making carbon-free alloys, and the authors' paper would be useful to him. The authors' apparent effect of nickel on the beta transformation was shown by a horizontal line in their equilibrium diagram; he asked whether they could rely upon that line being absolutely horizontal.

Mr. D. Hanson realised that it was essential to give as much as possible of the composition of the alloys. It was, however, difficult work, carried out on very small specimens, and they did not use up more than could be helped on analyses. The manganese was practically nil, and the alloys could be called manganese free. He (the speaker) had tried to produce martensite in commercially pure iron and had failed; Dr. Thompson probably had not iron containing less carbon than the alloys referred to in the paper. The authors had used the points on the cooling curves for their diagram; it was questionable as to whether the heating or the cooling curves gave the more reliable data. They had found them, he might add, reversible to within a few degrees only. Nitrogen could have but very little effect; the samples before working were annealed in vacuo and were, therefore, nitrogen free. He referred Mr. Greenwood to the diagram, Fig. 3, showing that the beta transformation was lowered by the presence of nickel.

(To be continued.)

THE LATE SIR JAMES BENJAMIN BALL.

MANY of our readers will learn with great regret of the death of Sir James Benjamin Ball, which occurred suddenly from heart failure on Friday last, at Forest Row, Sussex, where he was staying on a visit to Sir William Forbes. The deceased gentleman was, of course, the engineer-in-chief of the London, Brighton & South Coast Railway (of which line Sir William is the general manager), and the knowledge of his death, at the comparatively early age of 53 years, will come as a shock to his many friends among railway and other engineers.

Sir James was born on March 9, 1867, was educated privately, and was articled to Mr. Joseph Hall, Assoc.M.Inst.C.E., in 1884, and later was Mr. Hall's assistant on sewerage works, surveying, and in connection with Torquay harbour and pier schemes. He also acted as resident engineer on breakwater repairs, and later, in 1888, became resident engineer for a firm of contractors engaged on road construction and sewerage work in the Isle of Wight, and also on the widening of Newport Station. After acting for a short period as assistant to Mr. Urban Smith, Assoc.M.Inst.C.E., County Surveyor of Hertfordshire, in connection with the preparation of a scheme for sewerage and sewage disposal at Bushey, he became, in 1890, assistant to Mr. Richard Johnson, M.Inst.C.E., then chief engineer to the Great Northern Railway, since which time the whole energies of the subject of our memoir have been devoted to railway work.

While in the service of the Great Northern Railway Company, Mr. Ball, as he was then, was engaged in the preparation of drawings and estimates for numerous stations, engine sheds, erecting shops, goods warehouses, &c., and also in the design and equipment of oil-gas plants. In connection with the latter work a reference should be made to a paper he read at a students' meeting of the Institution of Civil Engineers in March, 1892,* describing the manufacture of oil gas at the Holloway Works of the Great Northern Railway Company for use with the Pintsch system of train lighting. This paper was awarded a Miller Prize, and shortly afterwards Mr. Ball was elected an associate member of the Institution. On terminating his engagement with the Great Northern Railway, in 1895, Mr. Ball became assistant to Mr. Elliott-Cooper (now Sir Robert Elliott-Cooper), Past-President of the Institution of Civil Engineers, and was occupied for about three years in the preparation of drawings and specifications of bridges, stations, warehouses, &c., for the Lancashire, Derbyshire & East-Coast Railway, afterwards superintending the constructional work. He also acted as resident engineer on the Shirebrook Curve and the Calow & Bonds Main Joint Railways, and was engaged in Parliamentary work in connection with several important projected lines. In December, 1898, he was appointed engineer of the Lancashire, Derbyshire & East Coast Line, having sole charge of the maintenance of way and works, as well as of the design and construction of new works and connections. This position he occupied until 1906, when the line was taken over by the Great Central Railway Company, and Mr. Ball was given charge of the new-works department. Five years later he was appointed engineer-in-chief to the Great Central line.

His connection with the Great Central Railway continued until 1917, and it was during this period that the most important work of his life was carried out. He was responsible for many heavy development works on the line covering a total expenditure of several millions. Of these works we may mention the widening of the line between Ardwick and Hyde Junction, between Doncaster and Thorne and between Wrawby Junction and Brocklesby, as well as the construction of the Keadby Deviation Railway. The latter work included the construction of a combined road and railway bridge over the River Trent, having a lifting span of some 165 ft., and Mr. Ball gave a very complete account of the design and construction of this bridge in a paper read before the Institution of Civil Engineers in November 1916; for this paper he was subsequently awarded the Telford Medal.* Other work by Mr. Ball for the Great Central Railway included the improvement of the ventilation of the Woodhead Tunnels on the main line between Manchester and Sheffield, and the equipment of the new docks at Immingham with hydraulic appliances, reinforced concrete bridges, grain silos, &c., as well as the laying of some 170 miles of track. A full account of the Immingham Docks will be found in ENGINEERING, vol. lxxxvii, pages 653 and 717, and vol. xciii, pages 816 and 840.

SIR JAMES BENJAMIN BALL.

In February, 1917, Mr. Ball was appointed chief engineer to the London, Brighton & South Coast Railway, in succession to Mr. C. L. Morgan, who retired from that position and joined the Board of the Company. A few months later, however, Mr. Ball's services were loaned to the Government for work in connection with the war, and he was then appointed Controller of Timber Supplies by the President of the Board of Trade. In this capacity he did most valuable work in organising the timber resources of the country at a time when organisation was essential to the successful conduct of the war. He was also responsible for some important dock and railway work, especially in connection with the development of Newhaven as a port for war operations. In recognition of his services in this connection he was created a Knight about two years ago.

The deceased gentleman was transferred to full membership of the Institution of Civil Engineers in 1902, and was elected a member of the Institution of Mechanical Engineers in 1914. He was President of the Permanent Way Institution in 1906, and was largely instrumental in bringing about the incorporation of that body. He was also a Major in the Engineer and Railway Staff Corps. Sir James was twice married, and leaves three daughters by his first wife and one son by his second wife.

* See Proc. Inst. Civil Engineers, vol. cx, page 324.

* A complete account of the Keadby bridge will be found in ENGINEERING, vol. ci, page 592, and vol. civ, pages 456, 485, 541, 593, and 649.

THE BRITISH ASSOCIATION.

(Continued from page 385.)

SECTION B.—CHEMISTRY.

SECTION B suffered somewhat from the fact that, owing to several circumstances, its programme was not quite settled when the "Journal" was printed, though finally the alterations in the agenda were not greater than in other sections. Some rearrangement of the papers must always be reckoned with. But the chemical section is in a difficult position. Communications from the domain of physical chemistry find larger audiences in Section A; papers of technical interest are generally brought before the Society of Chemical Industry, which has its own annual gathering, or before other bodies; and pure chemistry does not attract the general public so much as it did in the early years of the British Association, when chemists named their "Beehive" club after the second Section B of the Association. At Cardiff the excursions to works were a prominent feature. Some of the general discussions, more suitable for the meeting than specialised papers would have been, dealt with subjects on which interesting information had been published within the previous few weeks.

In the absence, through illness, of the Recorder of the Section, Dr. A. Holt, of Liverpool, Professor C. H. Desch, D.Sc., of Sheffield, took up the duties of the Recorder, assisted by Professor E. P. Perman, D.Sc., the local sectional secretary. Mr. C. T. Heycock, M.A., F.R.S., of Cambridge, was the President of the Section, and Professor P. Phillips Bedson, D.Sc., of Newcastle, Vice-President.

METALLIC ALLOYS.

In his presidential address Mr. Heycock dealt with the manner in which our present knowledge of alloys has been obtained. Starting from the sparse information available forty years ago, he referred in particular to the work of Sorby, of Matthiessen and of F. Guthrie. Interested by a paper of J. Rea on the comparative saltness of the freshly-formed and of the old ice of the Arctic regions, Guthrie found, in 1875, that the freezing-point was lowered as the salt percentage increased, that the first ice which fell out was pure water, and that at the point of saturation ice and salt separated simultaneously, the solid and liquid portions being identical in composition. Guthrie also named the mixture of lowest melting point a eutectic. The molecular depression of the freezing points, by dissolving various substances in various (including organic) solvents was further studied by Raoult, but the matter remained empirical until Van't Hoff proved, in 1888, that dilute solutions behaved as if the solute were a gas. Next, in 1889, F. H. Neville and Mr. Heycock himself showed that the freezing point depression was also proportional to the concentration of various metals dissolved in fused tin, and this observation was almost simultaneous with Tammann's similar work on mercury alloys. Neville and Heycock concluded that in the case of most metals dissolved in tin the molecular weight was identical with the atomic weight, in other words, that the metals in solution were monatomic—a conclusion which involved certain assumptions.

By the time that the Alloys Research Committee of the Institution of Mechanical Engineers took the study up in 1890, delicate measuring instruments had been discovered in pyrometers (resistance thermometers and thermo-couples), and

Stokes later suggested to Neville and Heycock microscopic examination of the alloys, slowly cooled or chilled, in order to explore, in the first instance, the singularities of freezing-point curves, and of liquidus and solidus curves, of copper-tin alloys. Mr. Heycock laid stress upon the fact that without the aid of guiding theories—such as the phase rule and the solution theory of Roozeboom—the interpretation of the results would have been impossible. The outcome of such researches, which he briefly summarised, had been that many rare laboratory products had, during the last decades, become most important industrial products, and that scientific industries had grown up. From that point of view one had to consider the effect donations and bequests like that of the British oil companies to the Cambridge School of Chemistry (200,000*l.*), and those of the late Dr. Messel, Dr. Mond, the City companies and others. Within the last few weeks one great chemical-manufacturing concern had devoted 100,000*l.* to research. The most pressing need of the present day was, perhaps, the cultivation of a better understanding between our great masters of productive industry, the shareholders, to whom they were in the first degree responsible, and the scientific workers.

Industrial Alcohol.

In his survey of the position of industrial or power alcohol, Captain A. Desborough, of the R.N. Cordite Factory, Holton Heath, Dorset, confined himself to the problem of economical production. It will be seen from the following abstract of his address that he was able to give definite information on matters frequently treated on general lines. As regards calcium carbide, definite cost figures were difficult to obtain. According to the most concrete figures available, the German official report of 1918, the Lonza Works, in Switzerland, contracted to supply a rectified alcohol to the Federal Government at 1*s.* per gallon; but it was problematical whether alcohol from carbide could ever compete with fermentation alcohol, since calcium carbide converted into calcium cyanamide and utilised as a fertiliser (nitrolim) for potatoes, would indirectly yield four times as much alcohol as when directly converted into alcohol; the Lonza factory, moreover, was understood to have been closed down. By the conversion of ethylene (from coke-oven gas) into alcohol the Skinningrove Iron Works were said to produce an alcohol worth 2*s.* a gallon.

All the other alcohol processes were based on the fermentation of carbohydrates, cellulose, starch or sugar. As regards cellulose, the fermentation of sulphite liquors had obtained importance, and the liquor from the pulp mills of Canada could, according to the Advisory Research Council of Canada, supply 5,000,000 gallons of 95 per cent. alcohol at 1*s.* 6*d.* a gallon. In the Simonsen and Classens processes, worked in one American factory during the war, sawdust and wood waste were digested with sulphuric or sulphurous acids at high temperatures, to produce a fermentable sugar, dextrose. Waste cellulose certainly abounded all over the world; but the collection of the material offered serious difficulties and the acids required, even the hydrochloric acid of the Willstätter process, had like the wood to be brought long distances. The extensive utilisation of peat and seaweed for these purposes seemed to be out of the question. With respect to the more readily fermentable starch and sugar materials, the manufacturer, to place a 95 per cent. alcohol at 3*s.* 2*d.* per gallon on the retail market, would have to sell at 2*s.* 2*d.*, the distribution costing another shilling. But to produce that alcohol in a modern factory cost 9*d.* per gallon, including plant depreciation; with 2*s.* 2*d.* wholesale price, that left 1*s.* 5*d.* for materials and interest on capital, and putting the interest at 4*d.*, the allowance for raw material was brought down to 1*s.* 1*d.* per gallon produced. With 120 gallons obtainable from 1 ton of fermentable carbohydrates, the maximum price to be offered per ton of pure carbohydrates would be 6*l.* 10*s.* at the factory. The maximum economic prices, based on the carbohydrates present, payable per ton would thus be: artichokes, 1*l.* 3*s.*; potatoes, 1*l.* 3*s.*; mangolds, 11*s.*; sugar mangolds (with 13 per cent. of sugar), 17*s.*; maize, 4*l.* 8*s.*; rice, 4*l.* 17*s.* Whether it would be possible to bring the cost of mass production down to these figures was the crux of the whole problem. Artichokes, mangolds and potatoes seemed to be ruled out as raw materials; maize might answer, especially in countries like Peru where the price was supposed to be only 2*l.* per ton; maize-alcohol was, indeed, said to be made in South Africa.

There was, of course, the objection that foodstuffs could not be spared for power-alcohol manufacture, especially in view of the fact that Egypt and India had taken up the cultivation of cotton as better paying than raising foodstuffs. The objection would not hold for reclaimed waste ground, however, especially not when the producer of the raw material had a direct interest in the finished article, in other words, when the alcohol was produced on a co-operative system. Captain Desborough knew from his own observations that good artichoke crops had been raised on reclaimed land in this country, and that should not be overlooked. Many people seemed to think that the tropics alone could supply the raw materials; but the root crops (potatoes, yams, sugar-cane or beetroot) were, on the whole, more prolific in temperate climates than in tropical climates. Passing to their own work at Holton Heath, Captain Desborough mentioned that they were working in conjunction with the Department for Scientific and Industrial Research. They were reclaiming land; they were growing a special beetroot introduced by Vilmorin in France for alcohol manufacture; they were about to experiment with a tuberous helianthus plant found in the Andes at an altitude of 6,000 ft., the *polymnia edulis*, which gave tubers, resembling four bulbs grown together attached by a curved projection to the root, up to 2 lb. in weight and of fairly high sugar content; and they were also trying the direct fermentation of cellulose with sugar by an organism. Though the home wants of power alcohol could never be met by home production, it was too early yet to decry home production as uneconomical.

A good many questions were raised during the discussion of this paper, by Drs. Slade, T. M. Lowry, C. H. Desch, J. Reilly, N. V. Sidgwick, and others. It was agreed that, since plants convert atmospheric carbon dioxide into alcohol and power without drawing upon our coal stores, research on vegetable alcohol should be encouraged. German potato spirit was alluded to. Captain Desborough replied that this had been a subsidised industry; it might be added that agriculture, ploughing, reaping, distilling, &c., *is* or was largely co-operative, while electric power was being utilised in many districts, in which the individual owner would have a very hard struggle. It was also mentioned that the fermentation of copra, an important tropical product, was prohibited in the interest of native races. Several speakers referred to the conversion of ethylene into alcohol at Skinningrove, which had by no means been abandoned. The ethylene source could not be neglected, even if only to meet immediate wants. A resolution was finally passed urging the importance of continuing the present researches on industrial alcohol conducted in Government factories; this resolution was subsequently approved of by the Committee of Recommendations.

Fuel Economy.

We commented on the report of the Committee on Fuel Economy in our issue of August 27, page 285, but we wish to add a few remarks with regard to the discussion on the subject in Section B and on the production of power alcohol from coke-oven gas at the Skinningrove Iron Works by the process of E. Bury and O. Ollander. The debenzolised coke-oven gas there contains about 2 per cent. of olefines, chiefly ethylene with some propylene and higher homologues, and the first problem, to separate the ethylene from the tar, &c., as well as from the higher olefines, involves a certain modification of the crude gas treatment. At Skinningrove the Otto direct process is utilised for the elimination of the tar, ammonia, naphthalene, and the benzol hydrocarbons, in the order named. From the cooled gas sulphuretted hydrogen H_2S is eliminated by the well-known reaction between H_2S and SO_2 (sulphur dioxide) yielding sulphur and water vapour; by scrubbing the gas with sulphuric acid of 80 per cent., at ordinary temperature, the water vapour and higher olefines are absorbed. The cooled gas enters a heat exchanger, in which 95 per cent. sulphuric acid and the gas, both preheated to 60 deg. or 80 deg. C., remain in contact with one another on the counter-current principle for about 2½ minutes. Under these conditions—this is the essence of the process—rapid absorption of about 70 per cent. of the total ethylene is realised, ethyl hydrogen sulphate being almost alone formed; above 80 deg. ethyl ether would be produced. The acid solution of the ethyl sulphate meets a current of steam in a distilling column and is hydrolised into a 95 per cent. alcohol and diluted sulphuric acid mixture; the acid is concentrated in Gaillard towers, and any SO_2 liberated there is utilised for the decomposition of H_2S, as stated above.

During the discussion of the Fuel Committee report which was presented by its chairman, Professor W. A. Bone, F.R.S., references were made to the differences of opinion between the Committee and the Fuel Research Board and to the recent Bill on Gas Standards. Doubts were also expressed as to the advantage gained by limiting the amount of carbon monoxide in the gas to 20 per cent. This limit, Dr. Landor explained, had been fixed by the medical advisers.

Mr. Cosmo Johns said that a limitation of the gas composition was desirable for furnace working, though it might not matter for gas mantles. He also referred to the suspension of powdered coal in oil; the new refineries of the Anglo-Persian Oil Company near the anthracite fields of Wales should investigate that promising process. Dr. E. Stansfield further emphasised the high possibilities of this colloidal fuel, and stated that low-temperature carbonisation was under trial in a big plant in Saskatchewan. Professor Bone, in his reply, mentioned that the colloidal fuel problem was being studied by the Committee.

The Metallurgy of Tungsten.

The discussion on the "Metallurgy of Tungsten" was opened by Mr. Julius L. F. Vogel, M.I.E.E., &c., of the High Speed Steel Alloys, Limited, Widnes, who outlined the origin, manufacture and uses of tungsten. As the subject has repeatedly been noticed in our columns of late we will chiefly refer to points which have so far received less attention.

Mr. Vogel's remarks did not concern the purest tungsten, the production of which Dr. Coolidge* recently described. The two main tungsten ores, Mr. Vogel explained, required different treatments. Wolfram, a collective name for tungstates of iron and manganese, was mostly overlying tin ores, which were found at greater depths; it was easily washed free of silica, but not of cassiterite SnO_2, which was not magnetic like wolfram, however. The rarer mineral scheelite was calcium tungstate, a wax-like opaque non-magnetic material, very heavy like wolfram. Both the minerals occurred chiefly in alluvial deposits or in lodes and being friable were disintegrated by vegetable growth. They could be split up by acids; when sulphuric acid was used, the deposit was difficult to wash, and hydrochloric acid was too slow in its action; in both cases the vessels and the stirring of the heavy masses, which should be ground fine, caused much trouble. Scheelite was only used for the production of pure tungsten, since the presence of calcium in tungsten was very undesirable. Reduction of wolfram was possible in electric furnaces, the reducing agents being aluminium, silicon and carbon; carbon, however, would also form tungsten carbide. A little scheelite was added to the wolfram to make the slag more fusible. With large charges aluminium would recover up to 98 per cent. of the metal; a ferro-tungsten of 80 per cent. of tungsten was almost the highest grade alloy that would melt. Whether it was advantageous to use tungsten powder by preference to ferro-tungsten in the preparation of alloys was a controversial question.

In the usual German process of fusing the ore with soda the impurities of arsenic and phosphorus were very objectionable, because in the presence of

* See ENGINEERING, July 23, page 109 *ante*.

arsenic in particular some tungsten remained in solution when the solution of sodium tungstate was precipitated with hydrochloric acid, a little arsenic keeping sixty times its weight of tungsten in solution. The tungstic acid also became colloidal. The precipitated WO_3 was dried at 300 deg. C. or 400 deg. C. by gases which must be free of sulphur.

When carbon was used for the reduction, an excess of carbon had to be avoided; not to introduce more than 0·25 per cent. of carbon into the metal, the crucible should be slowly heated up and slowly cooled. Mr. Vogel added typical analyses of the ores and products to his paper. The specification for ferro-tungsten of 1917 demanded 75 per cent. of W, not more than 1 per cent. each of C or [Si, Mn, 0·25 per cent. of Sn, and tolerated very small percentages of S (0·06,) P (0·0257) lime (0·03); ferro-tungsten reduced by aluminium might contain 85·5 per cent. of W. The specification for tungsten powder called for 96 per cent. to 98 per cent. of W, and the permissible impurities of C, 0·50 per cent., Si, 0·30 per cent., Mn, 0·20 per cent., &c., were all much reduced; most commercial tungsten powder was superior to these standards. The prices of tungsten had fallen considerably since the removal of the Government control, because large stocks had accumulated, whilst the demand improved; the industry, however, required the protection of a key industry, though the improved methods of manufacture now in use were more economical in coal consumption than those which had preceded them.

Professor C. H. Desch mentioned during the discussion of this paper that the tensile strength of the originally brittle tungsten could, by swaging in hydrogen, be raised to 270 tons per square inch in wires 0·0011 in. in thickness; tungsten differed from other metals in being more ductile when cold after severe working than in the annealed condition. The possibility of drawing tungsten cold depended upon the grain size; ingots were examined microscopically and were rejected, if the grain size exceeded certain limits. The grains grew on long exposure to high temperature; in order to prevent this growth from becoming excessive, rendering the filaments brittle, a small quantity of thoria was, in lamp wire works, mixed with the tungsten powder in making the ingots, the infusible and non-volatile particles of this oxide presenting an obstacle to the growth of the grains. Mr. Vogel did not allude to this practice.

THE ZINC INDUSTRY. ELECTROLYTIC ZINC.

The remark about the protection of the tungsten industry against foreign competition which Mr. Vogel had made in concluding his paper on that metal was repeated by Mr. Samuel Field, A.R.C.S., F.C.S., of London, in introducing his paper on the "Zinc Industry." During the Government control the prices of zinc had soared up from 23*l.* per ton to 115*l.* per ton; "the removal of the umbrella" had produced a marked depression, evidenced by the melancholy procession of large spelter works now passing out of operation." The pre-war consumption of zinc in Great Britain had been 224,000 tons; Great Britain had supplied 58,000 tons, and similar amounts had been introduced from Belgium and Germany. The present production amounted to less than 10 per cent. of the pre-war consumption. The zinc distillation method was severly handicapped by the scarcity of suitable pure raw materials, the poor recovery from any but the highest grades with the best type of fuel, by a very low thermal efficiency and by the poor quality of the product, apart from high labour and fuel costs. Elsewhere electrolytic zinc processes had been adopted, and British electrolytic zinc was now also an economic proposition. Researches had been carried out at Swansea for four years, over 120 tons of zinc had been produced of late in a 1½ ton plant, and it had been proved that superior electrolytic zinc could be produced even from the complex ores available in the country and at greater efficiency than by distillation. In purity the product ranged up to 99·95 per cent., the recovery was high, lead and silver were likewise recovered. Moreover, the handling of material was almost entirely mechanical, and the availability of home ores, not amenable for distillation, was an important advantage.

The information which Mr. Field gave about the actual process was rather general. The sulphide ores, he stated, were calcined, the sulphur being recovered as sulphuric acid or as sulphur; the zinc sulphate was extracted with the acid liquor from the electrolytic cells, and the solution produced was neutralised by adding ore, and finally waste zinc and whiting. The difficulty of preventing the formation of a siliceous gel had completely been overcome. The liquor separated from the insoluble residue of lead and silver (recovered as argentiferous lead by smelting) contained about 10 per cent. of zinc together with impurities of arsenic, antimony, copper, iron, nickel, cobalt—all undesirable. These were removed in a two stage or one-stage operation, until only traces of cadmium, nickel and cobalt, each less than 1 : 1,000,000 were left. The purified liquor was acidified with solution from the cells and electrolysed with lead anodes and aluminium cathodes until the electrolyte starting with 8 per cent. of zinc and 3 per cent. of acid, contained 3 per cent. or less of zinc, whilst the acidity was raised to 10 per cent.; this liquor was subsequently used for the extraction of the calcined ore and the acidifying of the solution. The cell took 3·5 volts on an average; the cathode density ranged from 25 amperes per square foot to 30 amperes per square foot, and the deposits were allowed to grow for two days; the current efficiency was 90 per cent. The zinc deposits were easily detached from the sheet aluminium and, after rinsing, were melted down to ingots, the percentages of impurities not exceeding Cd 0·02, Pb 0·02, Cu and Fe 0·01. Including mechanical power the electricity consumption was 4,000 k.w. hours per ton of zinc, less than half of that required for electrothermal reduction.

The crux of the problem is, of course, the purification of the electrolyte, and about that Mr. Field did not give details. Lixiviation of sulphidic zinc ores with acid zinc sulphate followed by electrolytic depositions of the zinc was introduced by Siemens and Halske in Silesia more than twenty years ago. But zinc is apt to fall out spongy even if the electrolyte be pure zinc sulphate; the impurities give trouble, and the electrodes too, as the adoption of expensive peroxide anodes (lead or manganese peroxide) proves; and electrolytic zinc extraction processes have not generally prospered, in spite of the manifest advantages they seem to offer. The experiments at Swansea are hence of considerable interest. We may add that electrolytic zinc works were erected in America during the war, and that such works have quite recently also been opened at Risdon in Tasmania.

(To be continued.)

LITERATURE.

The Engines of the Human Body: Being the Substance of Christmas Lectures given at the Royal Institution of Great Britain, Christmas 1916–17. By ARTHUR KEITH, M.D., LL.D., F.R.S. London: Williams and Norgate, 1919. [Price, 12*s.* 6*d.* net.]

THE advance in the methods of education is well shown by the improvements that have been made in the elementary books especially prepared for children, and the care taken to ensure that the information should be both accurate and entertaining. Occasionally some work appears in which the well-intentioned, but ill-equipped, author repeats the method and the faults that marked the productions of Miss Magnall or the author of the "Child's Guide to Knowledge." But such revivals of obsolescent learning only serve to give greater prominence to the valuable treatises of those masters of language as of science, who are willing to undertake the task, of preparing elementary works, if thereby they can make more certain and attractive the early steps along the road of real knowledge. Among such enlightened efforts this book ought to have a conspicuous place, as it throws illuminating rays on an obscure subject, and excites intelligent curiosity by illustrations that delight by their ingenuity and instruct by their appositeness. The book had its origin in a course of Christmas lectures, given by Professor Keith to a juvenile audience, at the Royal Institution, in the Christmas holidays 1916–17, a continuation of a remarkable series to which many scientific men have been proud to contribute, and who have set up a standard, to which educational lectures must approach, if they are to be successful.

The juvenile critics who form the audience must be approached with judgment and discretion, if they are to be neither bored nor bewildered. Mere simplicity of language as Professor Keith reminds us will not make a lecture instructive, nor remove the obscurities that inherently attend the introduction of a complex subject, as physiology. New and fresh machinery must be "used for the display of old facts, one which will give opportunities of unveiling in their proper place and perspective, the more recent advances made by anatomists and physiologists." The scheme which Professor Keith adopted to hold the attention and impress his audience was to institute a comparison between the mechanism of the body and the products of the engineer's workshop, to trace the correspondence of parts in the motor bicycle and the human machine. Other comparisons had to be found as the lectures advanced to the consideration of nerves and of brain, but the bicycle, a mechanism of which every boy might be supposed to know something, remained the favourite. In many respects, the contrivances of the bicycle were found to be inferior to the arrangements adopted by Nature, and these deficiencies were insisted upon with considerable emphasis. This attitude recalls in some way the plan or object of the Bridgewater Treatises of a century ago, but Professor Keith has many more facts at his command, and if he does not mention the word evolution from start to finish, he has entered into the labours of those who have developed the science, and his book is the richer and more suggestive on that account.

To carry out his plan it was necessary to construct models of the human frame and of the motor bicycle engine. A Goliath of coloured cardboard represented the human model, of whose appropriateness the lecturer must have been convinced, when he attacked the mysteries of acromegaly and described the troubles of giantism. Goliath was a working model, it was furnished with bones that would fit into real joints, and move as in life. The proper muscles were arranged round these dry bones, the interior was equipped with a heart and pumping machinery to make the blood flow outwards, and veins to bring it back again to the heart. The lungs were supplied with a windpipe along which air could be made to pass, and the stomach and intestines were fitted into their appropriate places. The brain, "Nature's master contrivance," was not forgotten. The separate parts of the whole were so contrived that they could be taken to pieces to demonstrate the internal mechanism. The care bestowed upon the preparations was not only a mark of respect to the intelligence of the juvenile audience; it showed that the lecturer thought accuracy and exactness were of prime importance, when taking the first steps in a new subject. We hope Professor Keith had his reward in the pleasure and interest evinced by the children, of whom he tells us "not many ever went to sleep."

Dr. Keith's programme was fairly simple when demonstrating that the bones of the body act as levers, or in comparing the muscles with the engine of a motor cycle, pointing out the resemblances and the disagreements. But the tale is told in a way that will prove convincing to the ignorant, and give the most instructed new views and matter for consideration. He decided that our muscles are really internal-combustion engines for they are supplied with an explosive mixture through the blood, and as a consequence heat is generated, and water and carbon dioxide are formed. But there is this difference, that in the human frame CO_2 is not thrown off at the moment of contraction, but afterwards. In this connection it may be noted that the author quotes the Croonian Lecture of 1917, by Sir W. Fletcher and Professor Hopkins, a proof that the latest facts and information can be put before an uninstructed audience, if they are presented in the right way. At the same time, an additional interest is provided by recreating the great masters of the past, who have succeeded in unravelling the riddles that perplexed many generations. The barriers of time are broken down

and we are permitted to see Harvey at his work and to appreciate the difficulties he met, the skill with which he encountered them, and the success that attended perseverance directed by energy. Priestley and Black figure as early chemists, Hunter and Charles Bell as anatomists. The past and the present meet together on the common ground of the furtherance of science, the aim of each has been to discover the truth and make the path easier and more certain for those who follow.

Another simile which is admirably worked and called "a transport system" is used to describe the processes by which food is conveyed through the human system. An accommodating friend "of medium, but spare build" was so obliging as to swallow a quantity of porridge, and the progress of this delicacy was followed on its journey of 28 ft., through a period of 24 hours, by means of the X-rays. A harmless salt of bismuth had been mixed with the porridge, which rendered the food opaque to the X-rays, and therefore could be photographed through all its changes as it passed from the pharynx till it left the body. This section of the lectures was probably much enjoyed, not only on account of the ingenuity and completeness of the illustrations, but also as the lecturer inveighed against the use of strong aperients, as tending to promote the very condition which Nature was trying to prevent by means of an ingenious mechanism. No doubt, too, hearty approval was given to the expressed conviction that the greatest zests of life are centred round the supply of wants created by a robust digestive system. There were many things which could not be explained, but Professor Keith is not one who is afraid to confess ignorance, he is ready to admit that there are artifices whose mechanism is so skilfully concealed that up to the present all inquiry has been completely baffled.

In addition to transport and conveyance our bodies possess in the nerves a telephonic system co-operating with numerous automatic exchanges. As the more intricate parts are approached where operations are apparently influenced by motives or intelligence, or where organisation between the different organs is essential for co-ordinated movement, the original comparison of the motor cycle recedes more into the background. What answered excellently well when the body was regarded as a moving machine furnished with muscular engines, levers, pumps, and bellows, no longer serves. Fresh comparisons have to be made and similes grow more fanciful. We have a postal system where the blood is the vehicle which carries certain missives prepared in the hormone factory designed to effect different operations in the human frame both functional and developmental. We may learn from this rather grotesque metaphor, that when a great effort is required from the body and the muscles are consuming fuel rapidly, that this extra supply is provided by the adrenal hormone. A message is sent through the liver to stimulate the sugar-producing laboratory of that great gland to set free its stores in the blood. These stores are carried by the circulation to the muscular engines and keep them supplied with the necessary fuel. This is only a part of the wonderful machinery that recent research has demonstrated; there are many others which this interesting book discloses.

Finally we come to the repairing shops, and are told how the human machines which break down on the road of life are again made to operate with fair efficiency, under the kindly action of a beneficent Nature. We are told of a caste system in which the several members have to fill an allotted vocation. Sometimes there is a caste mutiny when one caste breaks through into the territories of surrounding castes, and works much mischief which medical men describe as a cancer. If the process involved in such a mutiny is correctly understood, then, says Dr. Keith, "the discovery of the prevention of cancer will come to the man who finds out the manner in which Nature regulates the lives of the microscopic units of that most highly organised of all Empires "The Human Body."

WATER POWER CONCESSION IN UGANDA.—The Crown Agents for the Colonies announce that the time limit for the receipt of applications invited by the Government of the Uganda Protectorate for a concession of a portion of the Ripon Falls of the Nile has been extended to February 19, 1921.

THE LATE SIR WILLIAM MATHER, P.C.

THE death of the Right Hon. Sir William Mather, P.C., which took place on Saturday last at his residence, Bramble Hill Lodge, in the New Forest, will be deeply regretted by a wide circle of friends and acquaintances. At his death Sir William was in his eighty-third year, having been born at Manchester on July 15, 1838, being the son of Mr. William Mather, one of the founders of the Salford Ironworks. He was educated at private schools in England, and after attending technical lectures at Dresden, was apprenticed at his father's works, a plan which is not, it may be added, in all cases judicious. With youths of the proper capacity and temperament, however, the prospect of rapidly attaining to a position of authority is an urgent incentive to work, and in the present instance William Mather made the fullest possible use of his opportunities, attending evening classes after his day's work in the workshops which started at 6 a.m. In 1862, when but 24 years of age, he was taken into the partnership, and making good, took over the sole management of the business in 1871.

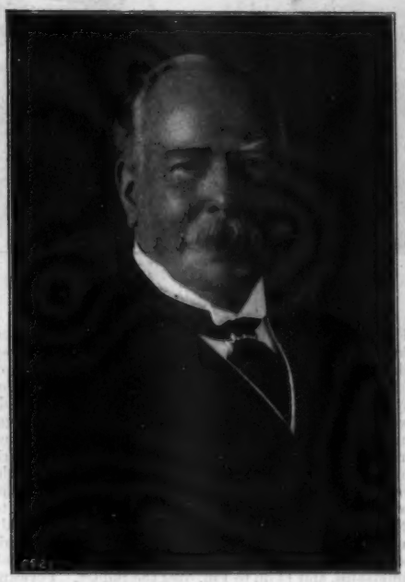

Photo Elliott & Fry.

SIR WILLIAM MATHER.

In this position he was responsible for the fine display made by his firm at the Vienna exhibition of 1873, which was recognised by his appointment as a Knight of the Austrian order of Francis Joseph. Recognition of this kind was, as usual, much slower in this country, as was well illustrated by the case of Sir Henry Bessemer, whose recognition by the Crown followed long years after foreign potentates had set the example. In Sir William's case the British knighthood was conferred in 1902, and was no doubt largely in recognition of his political, rather than of his technical achievements.

In 1877 the elder partners retired from the firm, leaving Sir William in full control. He was quick to recognise the value of innovations, and his firm were, we believe, the first to make compound high-lift turbine pumps, of which Osborne Reynolds was the original inventor. Pumps of this kind are particularly well suited to an electric drive, and the type would probably have been developed on a large scale in this, the country of origin, had it not been for the shortsighted and mischievous electric lighting Acts of Mr. Chamberlain which transferred to foreign brains the task of "practicalising" electrical machinery. The effect of this foolish legislation was even more directly disastrous in another venture made by the subject of our memoir. In 1882 Sir William acquired the manufacturing rights for the Edison dynamo, a machine which at that date had an efficiency of somewhere between 60 per cent. and 70 per cent. As the result of the researches made for Sir William Mather by the brothers Hopkinson, this efficiency was raised to 94 per cent., and the true theoretical principles of dynamo and motor design established for the first time. Unfortunately, thanks to our politicians, where our engineers sowed others reaped, and trade worth untold millions was diverted from this country. The electrical department of the Salford works accordingly remained of modest dimensions, when compared with the factories developed abroad manufacturing generators on the principles first laid down by Dr. Hopkinson.

Sir William Mather took an intense interest in educational matters, notes by him on conditions in the United States, Canada and Russia were embodied in the report to Parliament of the Royal Commission of 1881 on Technical Education. These reports were the results of visits made to these countries as a Special Commissioner. He started a science school for his own apprentices in 1877, and made attendance at these classes or at other technical lectures compulsory on all. He was consulted frequently by the Whitworth Trustees with reference to the due disposal of the funds left for public purposes by Sir Joseph Whitworth, and played accordingly a prominent part in the foundation of the Whitworth Institute of Art and Industry, which embraces the Manchester Technical School, to which, moreover, he was personally a liberal contributer. As the result of a visit to the Soudan in 1903 he presented the Gordon College with an entire outfit of machines and tools. He was, moreover, a governor of the Victoria University.

As far back as 1893 he introduced the eight-hour system into his works, and the change proved most successful and was permanently maintained.

He took a great interest in politics, and sat in Parliament for eleven years, being elected for Salford in 1885, and he subsequently represented the Gorton and Rossendale divisions of Lancashire. In 1901 he was placed on the committee for the re-organisation of the War Office, and in 1910 he was created a Privy Councillor.

He married in 1863 a daughter of Mr. Thomas Watson, of Highbury, and had one son and four daughters.

BRITISH PRODUCTION OF PIG-IRON AND STEEL IN AUGUST.—The production of pig-iron in August amounted to 752,400 tons, or 2,000 tons more than in July, which was the previous best. The production included 284,700 tons of hematite, 233,300 tons of basic, 137,300 tons of foundry and 58,600 tons of forge pig-iron. The production of steel ingots and castings was adversely affected by holidays, and amounted to 709,200 tons, compared with 789,900 tons in July.

ALCOHOL FUEL PATENTS. WARNING TO INVESTORS.—We have received the following for publication: The Empire Motor Fuels Committee of the Imperial Motor Transport Council has recently been considering the abnormal and unhealthy activity shown by pseudo-inventors in respect of alcohol motor fuels and mixtures containing alcohol. Shortly before the House rose Mr. E. Manville, M.P., at the request of the Empire Motor Fuels Committee, addressed the following question to the President of the Board of Trade: "If the Patent Office will pay special attention to the number of applications for letters patent in respect of admixtures of such bodies as alcohol, ether, kerosene, benzol and toluol, as motor fuels, in which applications no element of novelty, discovery or invention appears to be disclosed; and if he will give instructions to the Patent Office to be especially careful not to hamper or prejudice the production or utilisation of new motor fuels by the creation of ground for litigation in respect of alleged master patents." Sir Robert Horne's reply was that "Full and proper consideration will be given to all applications for patents in respect of inventions relating to new motor fuels before the patent is granted. The Comptroller of the Patent Office in considering what is a proper subject of a patent is, of course, bound by the provisions of the Patents and Designs Act in accordance with which he must act." It is felt by the Empire Motor Fuels Committee that great damage may be done to the prospect of early production and marketing of new motor fuels if disregard is shown by the Patent Office for the known miscibility within various limits of alcohol, benzole, petrol and other hydro-carbons and carbo-hydrates, and the committee wishes to give warning to the investing public that any claim to a master patent should in any conceivable circumstances be viewed with the maximum of doubt. The committee feels it is regrettable in the public interests that the Patent Office should be allowing patents to be granted for mixtures which every chemist knows can be employed as fuels and which every engineer knows are more or less applicable in existing engines or in engines slightly adapted in order to suit such mixtures.

GEARED TURBINE PROPELLING MACHINERY OF H.M.S. "RALEIGH."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LIMITED, ENGINEERS, DALMUIR.

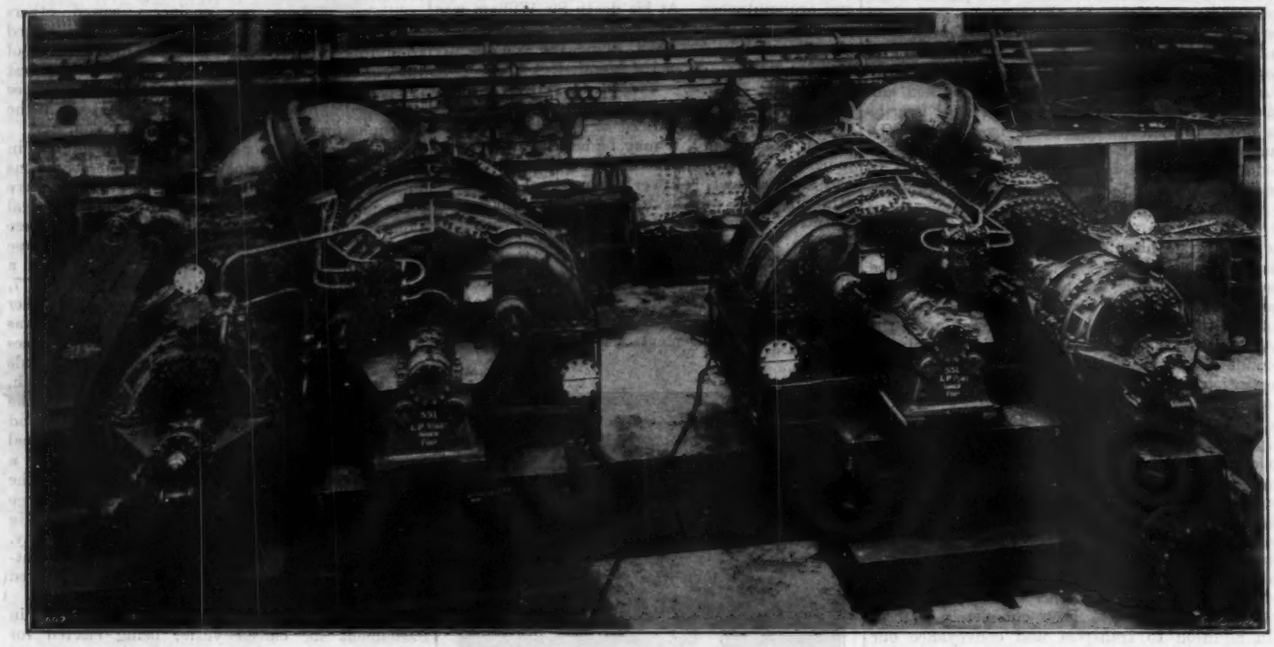

FIG. 5.

THE TRIALS OF H.M.S. "RALEIGH."

AN event of more than passing interest is the completion of the steaming trials, last week, on the Clyde, of the armoured cruiser H.M.S. Raleigh, built by Messrs. William Beardmore and Co., Limited, at the Naval Construction Works, Dalmuir. This completes a series of some 30 war vessels delivered by her builders during the war. The designs for this particular class of ship were prepared in the summer of 1915, but the completion of construction was delayed because of the inevitable changes of the programme of naval construction due to the necessities of the various phases of the war. The leading consideration was suitability for ocean work in any part of the world, so that a large radius of action was essential. Moreover, to act as a flagship of cruiser squadrons of "C" and "D" class cruisers a speed of at least 29 knots would be required. These features necessitated an increase in size. The 420 ft. length of the "C" class and the 445 ft. of the "D" class were increased to 565 ft. between perpendiculars, or 605 ft. overall in the case of the "Raleigh" class, with corresponding increases in the other leading dimensions. A beam of 65 ft. with a draught of 17 ft. 3 in. gave a displacement in tons of 9,700, and 30 knots speed at load draught required a shaft horse-power of 60,000. A view of the vessel on her trials is given in Fig. 1, page 410, while elevations, etc., are given in Figs. 2, 3 and 4 on that page, illustrations of the turbines being given on this and the opposite pages.

The fuel carried totals 2,400 tons, 1,600 tons of oil and 800 tons of coal. In order to be capable of operating from bases where no oil might be available, it was decided to have a third of the total of 12 boilers coal-fired. The armament possible with the extra displacement was a considerable increase on the "C" and "D" cruisers, and consists of seven 7·5-in. guns, ten 3-in. quick-firers (four of which are high angle anti-aircraft), four 3-pounders, two 2-pounder pom-poms and six 21-in. torpedo tubes. The elevation and plan, Figs. 2 and 3, show the disposition of the guns, which are arranged so that six 7·5-in. are available on either broadside and four 7·5-in. ahead and four astern. The crews of the foremost and the aftermost guns, as will be seen from the illustration, are protected from the effect of the fire of the guns behind and above by blast screens, and the foremost gun on the quarterdeck is suitably masked over that part of its arc of fire interfered with by the aftermost gun. The six torpedo tubes are mounted as two single projectors in a submerged flat below the bridge and two pairs above water at the base of the main mast, as can be seen from the side elevation, Fig. 4. The normal beam is considerably increased by the "bulges," Fig. 4, although owing to the way the hull side slopes inboard—which lessens the risk of penetration by a dropping shot, besides making for speed—a perpendicular dropped from the top side would just touch the edge of the bulge. These bulges have proved most successful and their incorporation in this class of vessel follows on the successful experiment of H.M.S. Ramillies. As in the previous light cruisers there is 3 in. of armour over the side amidships with 2½ in. to 1½ in. extensions forward and 2½ in. to 2½ in. aft. Above this is a 1-in. strake so that only a very small portion of the hull at the extreme ends is left unprotected. The upper deck is 1 in. thick amidships, and 1½ in. to 1 in. over the rudder. Forward and aft are 1-in. bulkheads, and the combination of subdivision and bulges should permit of the ship remaining afloat with a large number of compartments flooded. The accommodation for officers and crew in the Raleigh is perhaps slightly better than is usual with this class of ship. A recreation room forward under the upper forward gun is an innovation in this class of vessel and the headroom of 8 ft. between decks makes for ventilation and general comfort.

During the construction, it was decided to ensure a good speed by increasing the power to 70,000 shaft horse-power, to which end the four coal-fired boilers had their capacity increased by suitable modifications to the oil-firing equipment, and the necessary alterations were made to the turbines to take the larger quantity of steam generated. The machinery presents features of interest as showing the solution adopted to instal such a large power in the very limited space available. There are altogether 12 boilers—eight oil-fired and four coal and oil-fired, of the Yarrow water-tube type. The eight oil-fired boilers have 7,650 sq. ft. of heating surface each. The figures for the boilers using coal and oil are 4,675 sq. ft. of heating surface and 77·58 sq. ft. grate area each. The latter boilers are located in the aft boiler room. The general arrangement of boilers, back to back in the forward and aftermost boiler rooms, but with the firing platform in the centre in the middle boiler room, facilitates the lead of the uptakes to the two funnels. To the larger funnel the uptakes from six oil-fired boilers are led, and to the other the uptakes are taken, serving two oil-fired and four coal and oil boilers.

The main machinery consists of four identical sets—two port and two starboard, each of three turbines of the Brown-Curtis impulse type. The cruising turbine is connected by a clutch direct to the forward end of each high-pressure turbine, which is connected in turn by a flexible coupling to the high-pressure pinion of the single-reduction double-helical gearing. The low-pressure turbine is similarly connected to its gearing. Figs. 5 and 6 give general views of the two sets of four turbines showing the turbines lined up to their gearing in Messrs. Beardmore's shops for steaming and balancing. In Messrs. Beardmore's engine shops the appliances available for testing the turbines under steam and the gearing at full speed are particularly complete. A battery of boilers of ample capacity and the necessary condensers, air, circulating and forced lubrication pumps are installed. In Fig. 6 the gear-case and gearing are more distinctly shown, the top part of the gear-case being lifted up and supported on columns and the pinion covers removed, so that the pinion with its bearings as well as the main gear wheel can be clearly seen. These two illustrations are reproduced from views which accompanied a short description of this vessel given in our columns at the time of her launch (see vol. cviii, page 340). The two outer propellers are driven by machinery in the forward engine room, and the two inner from the after engine room. The speeds of the turbines at full power are for the high-pressure 3,200 r.p.m., and the low pressure 2,150 r.p.m., with the propeller running at 420 r.p.m. All the shafts are fitted with Michell thrust bearings, as shown in the Fig. 3 of our previous article above referred to. A similar type of bearing is provided for taking the steam thrust of the turbines.

With this class of ship the auxiliary equipment forms a very important part of the whole machinery. The most important items of the present installation are as follows: Fifteen Weir's feed pumps, ten main and five auxiliary. For the three boiler rooms there are 12 steam engine-driven fans, supplied by Messrs. Paul, of Dumbarton. The oil fuel pumps, heaters and filters are accommodated in the boiler rooms; four Weir's dual air pumps and two Allen's circulating engines and pumps are disposed in each engine room. For electric power and light there are two Allen dynamos driven by compound reciprocating engines of a capacity of 105 kw. in each engine room. The main steering engines of Bow and McLachlan's build, are located on the after bulkhead of the after engine-room, and are each of the three-cylinder type, one engine being ample for the power and the other being a standby. For auxiliary steering gear the Hele-Shaw electric type is installed in an auxiliary steering compartment aft. Due to a recent decision that this ship should be a flagship in tropical climates, extra refrigerating machinery was installed.

The vessel was taken to the Tail of the Bank on Sunday, September 5, and there commissioned for trials. On Monday she proceeded down the Firth for her preliminary progressive and full-power trials,

GEARED TURBINE PROPELLING MACHINERY OF H.M.S. "RALEIGH."

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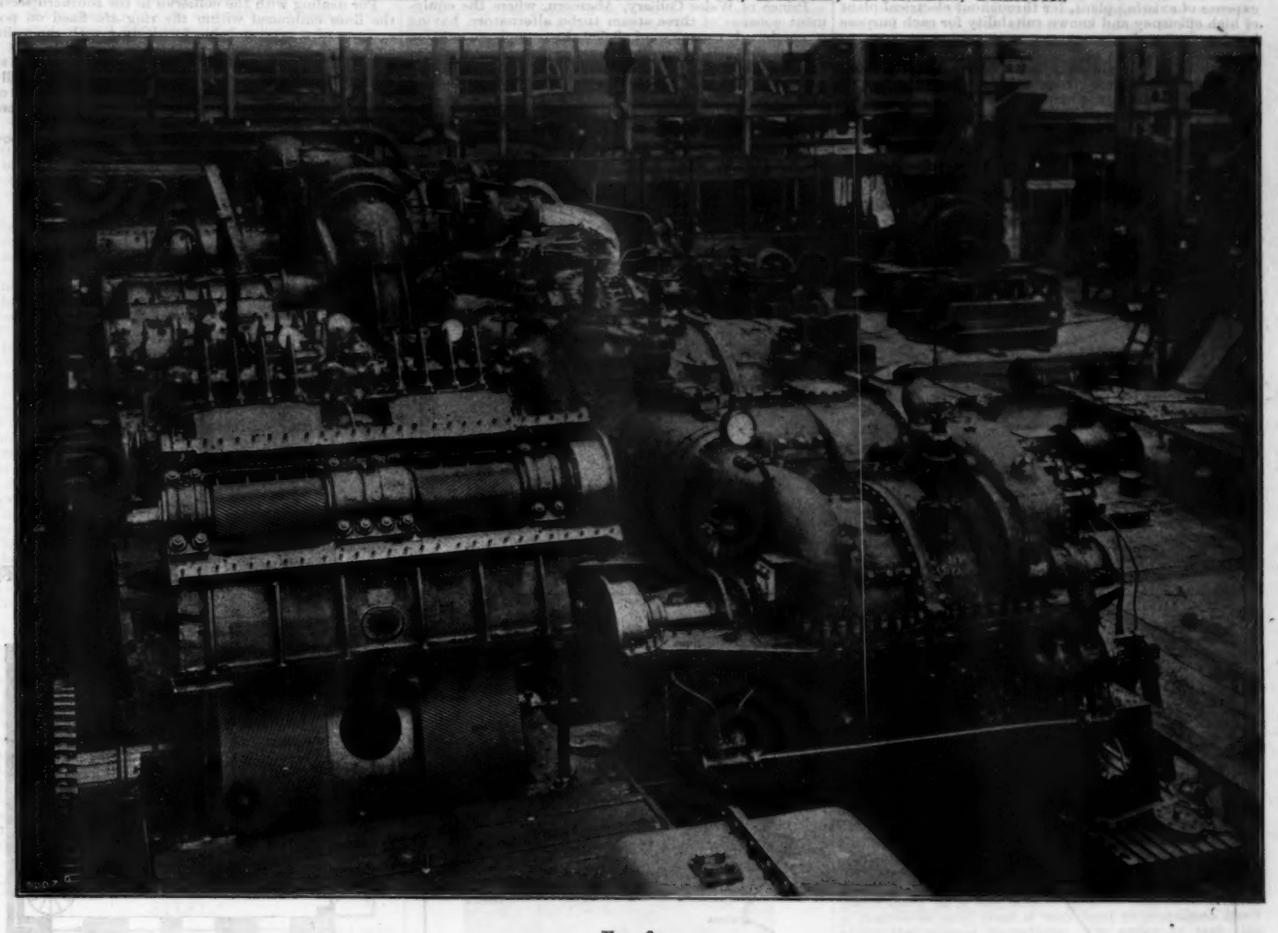


FIG. 6.

which were thoroughly satisfactory, and final progressive trials, working up to full-power trials of 4 hours' duration, were run successively on Tuesday, Wednesday and Thursday, September 7, 8 and 9. The various powers at which these trials were carried out were 3,000, 8,000, 15,000, 24,000, 35,000, 55,000, and full power of 71,350 shaft horse-power. At full power the excellent speed of 31 knots was attained as measured by four single runs on Arran double mile. On the progressive trials the cruising turbines were thoroughly tested, and the records of steam and oil consumption go to show a saving of oil fuel of some 15 per cent. to 20 per cent. at the economical cruising speed of 16 knots to 17 knots, due to the extra expansion of the steam possible by utilising the cruising turbine at the forward end of the high-pressure turbine. A remarkable feature of the performance of the machinery with this vessel was the fact that with one-half the nominal power, that is, 35,000 shaft horse-power, a speed of 28 knots was measured on the course.

During all these trials the ship proved herself a remarkably steady gun-platform and, except on the steering flat aft above the propellers, there was little evidence that anything like such high speeds were being attained. The machinery ran remarkably well and the noise of the gearing was not obtrusive. On Saturday, September 11, the Raleigh left for Devonport where she will be finally completed for her commission as flagship.

AGRICULTURAL TRACTOR TRIALS IN VALENCIA (SPAIN).—A communication has been received at the Department of Overseas Trade from the Commercial Secretary to H.M. Embassy, Madrid, in the course of which attention is called to the proposed trials of agricultural tractors to be held in Valencia, October 17 to 31, under the auspices of the Chamber of Agriculture. This event would appear to offer an excellent opportunity for British manufacturers of agricultural tractors to demonstrate the utility of the British-made appliances.

THE ELECTRIFICATION OF THE WORKS AND COLLIERIES OF THE EBBW VALE STEEL, IRON AND COAL COMPANY, LIMITED.*

By WALTER DIXON, M.I.M.E., M.I.E.E., &c.
(Glasgow).

AMONGST the works which are to be visited during the present meeting of the Institute in Cardiff are those of the Ebbw Vale Steel, Iron and Coal Company, Limited. At the time of the last visit—23 years ago—the company's properties were comprised in a comparatively small area, embraced within the site of the existing blast furnaces at Ebbw Vale and at Victoria, with several adjacent collieries, whereas at present the properties either owned or under the company's control extend almost continuously over an area of 15 miles north and south and 4 miles east and west, so that of its kind and within a continuous area, the works are to-day amongst the largest in the country.

As indicating the industrial importance of the company's workings, it is estimated that, with the completion of the schemes at present in progress, they will provide for an annual output of: Coal, 5,500,000 tons; coke, 575,000 tons; pig, 450,000 tons; while the allied industries embrace the manufacture of steel rails and sleepers, galvanised steel sheets, weldless steel tubes and couplings, coke-oven and blast-furnace by-products, iron and steel castings and engineering work.

It has been thought that some notes dealing with the electrical equipment of the company's properties would not be unacceptable at this time for the following reasons:—

1. Recent legislation promises to provide and render available a supply of electrical energy throughout the country in general, and therefore, amongst other districts, throughout South Wales, where there is thus an area of 60 square miles to 100 square miles being dealt with already as, and by, an independent concern.

2. The installation represents the development of the last 20 years, and to a great extent, therefore, it is the product of, and exemplifies the rise and development of the electrical industry in its relation to the iron, steel and coal industries.

3. From its inception the scheme has been in the same hands, those of Mr. Frederick Mills, as General Manager, Managing Director, and now Chairman of the company, together with the author, as Technical Adviser. It has, therefore, been possible for a scheme to develop uninterruptedly and according to a preconceived plan.

The following figures enable one to form an idea of the capacity of the plant installed in its relation to other local plants, the figures being taken from data compiled for the year 1917:—

	Plant capacity. kw.	Units generated. millions.
Cardiff Corporation	11,500	16
Newport Corporation ...	7,100	9½
Swansea Corporation ...	4,800	6½
Llanelly Corporation ...	3,300	5½
Total	26,700	37½
The South Wales Electrical Power Distribution Company	13,400	36

With the Ebbw Vale Company there is a continued and ever-increasing demand for power. At present the units generated per annum may be taken at 45,000,000, which will probably be increased in the immediate future to 60,000,000. The generating steam plant installed may be taken at 22,000 kw. From this it will be seen that the units generated at Ebbw Vale exceed either the figures given for the South Wales Power Distribution Company, or the combined outputs of the four principal corporation installations of Cardiff, Newport, Swansea and Llanelly.

The present site of the generating station is that of the original station, that site having been determined, because from the first the utilisation of waste gases was counted upon. It was centrally situated in the company's early properties, and regarded as being in a reasonable position for possible development requiring high tension transmission. With all its developments, the efficiency of electrical machinery throughout the past decades has not materially altered or improved,

* Paper read before the Iron and Steel Institute at Cardiff, September 21, 1920.

the result being that little or no replacement has been either desirable or necessary, and, speaking generally, it is believed that there is no modern development which the company would either on technical or economical grounds be justified in adopting at the expense of existing plant, for throughout electrical plant of high efficiency and known suitability for each purpose has been secured.

Incidentally, also, it is of interest to record that the plant has been practically immune from accident or breakdown, and free from other than intermittent stoppage, except in the case of a fire at the generating station. It is also gratifying to be able to report that there has been no fatal or even severe accident through electrical causes.

The other power stations are situated at :—

Six Bells Colliery, where the equipment consists of two 1,500 kw. mixed pressure turbo alternators, generating current at 3,000 volts, 50 cycles, and feeding a line through South Griffin to the Upper Deep Collieries.

Prince of Wales Colliery, Abercorn, where the equipment consists of three steam turbo alternators, having a combined capacity of 3,500 kw., and generating current at 2,000 volts, 50 cycles.

Cwmsychan Colliery, where the equipment consists of two combined engine-driven sets, generating current at 25 cycles.

Distribution.—The installation roughly divides itself into two distributing systems, as indicated in the accompanying plans (Figs. 1 and 2). Fig. 1 indicates in outline the district dealt with to the north of the generating station, and comprises the whole of the iron and steel works section ; and Fig. 2 indicates in outline the district situated to the south of the generating station concerned with the collieries. Direct current is taken to the steelworks from Victoria, and is transmitted on overhead cables to a distribution house in the steelworks.

The alternating current is taken from the switchboard in the generating station to the main substation shown at D, and is distributed to the northern area at 2,200 volts on a ring main system with balanced protective gear.

From various substations current is delivered at full voltage and also at 500–550 volts for general purposes. A supply is also being arranged for Trevil Quarries, situated some 4 miles to the north of the Upper Mills, transmission being arranged at 6,600 volts.

The substation D, besides providing for the above, is also utilised as a distributing point for the southern requirements as generally indicated in Fig. 2. A ring main on the split conductor system is being run from the distributing substation via Waunllwynd, Marine, Aberbeeg, Six Bells, Vivian, Tillery and South Griffin Collieries back to the substation, and the transmission is to be at 20,000 volts. From this ring branches will be fed to the collieries north of South Griffin, and also to the Cwmsychan group to the east of Tillery.

As indicated on the plan, certain collieries and works are connected with the generating station at the Six Bells Colliery, the transmission being at 3,000 volts. This recently acquired station is being connected with the main ring system.

There is under consideration an extension of the transmission system between Aberbeeg to Cwmcarn via the Newport–Abercarn Collieries and the Prince of Wales Colliery at Abercarn. In the meanwhile, however, there is no connection between Aberbeeg and Abercarn, although Abercarn and Cwmcarn are connected by a duplicate line, current being transmitted at 6,600 volts to the Cwmcarn Colliery, which is entirely electrified.

Transmission.—In the main, the transmission lines are erected on the overhead system, though in places it has been necessary to adopt underground cable. In the case of the steelworks, "H" poles of the ordinary type have chiefly been employed.

For dealing with the collieries in the southern section, the lines embraced within the ring are fixed on poles, and are of a type suitable for dealing with the voltage concerned, viz., 20,000.

Substations.—Figs. 3, 4 and 5 show the type of substation which has been adopted, from which it will be seen how provision is made for the incoming and outgoing supplies, the transformers and switchgear being arranged as shown.

Uses.—Throughout the steelworks electrical power is used for the hundred-and-one usual purposes. The various departments dealt with in this area, commencing with the substation, are : Sheet mills, dolomite plant, steelworks, upper mills, Ebbw Vale blast furnaces, spring and wagon shops, tube works, coke ovens, Victoria Colliery by-product plant, gas-cleaning plant, engineering shops and foundry, Victoria blast furnaces.

At the collieries electrical power is employed, amongst other purposes, for :—

	h.p.
Pumps to the extent of	3,200
Winders to the extent of	2,000
Ventilating fans to the extent of ...	1,300
Air compressors to the extent of ...	4,400

Continual additions are being made to each group.

Most of the collieries are arranged with their own substations, it being ultimately intended to render it

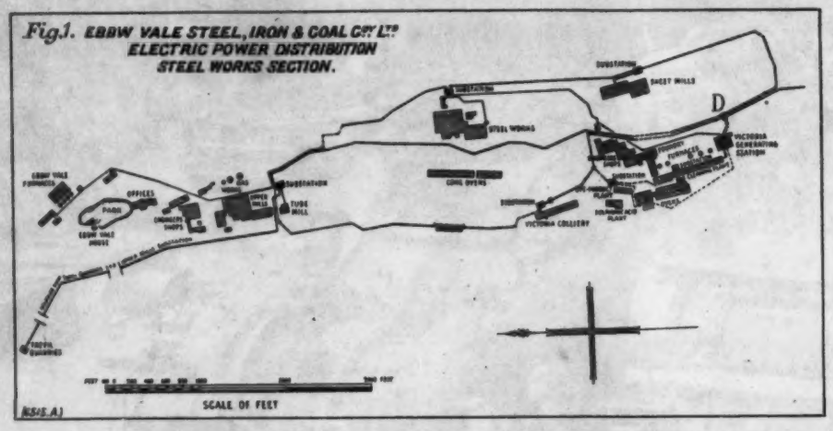


Fig. 1. EBBW VALE STEEL, IRON & COAL Co.ˢ Ltd. ELECTRIC POWER DISTRIBUTION STEEL WORKS SECTION.

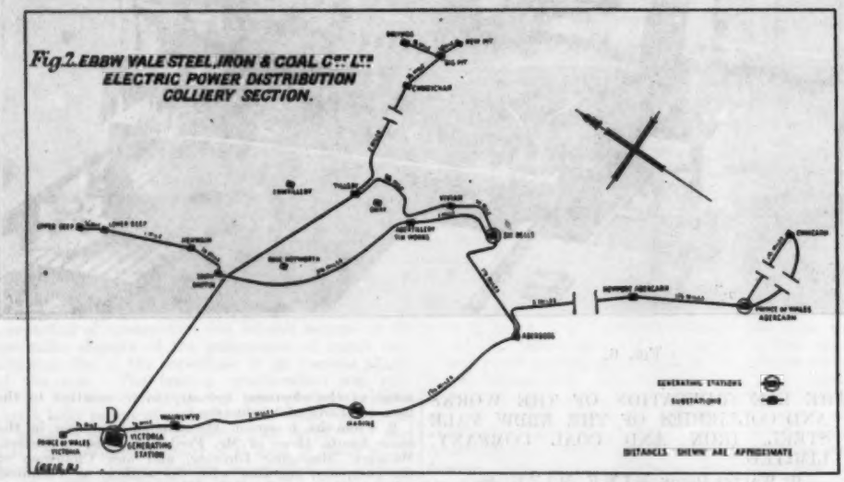


Fig. 2. EBBW VALE STEEL, IRON & COAL Co.ˢ Ltd. ELECTRIC POWER DISTRIBUTION COLLIERY SECTION.

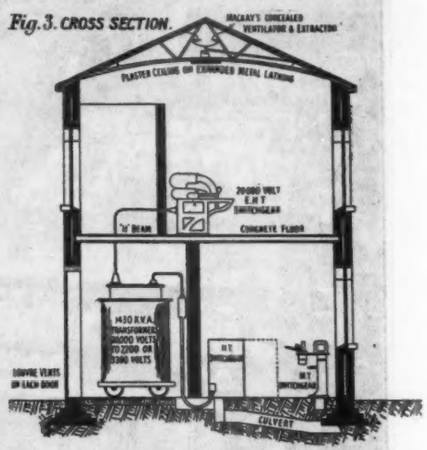


Fig. 3. CROSS SECTION.

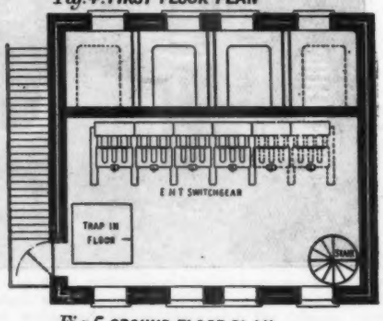


Fig. 4. FIRST FLOOR PLAN

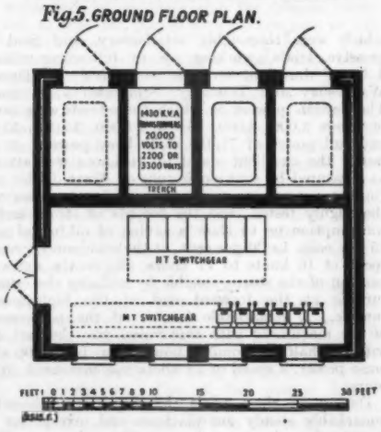

1430 K.V.A. TRANSFORMER 20,000 VOLTS TO 2200 OR 3300 VOLTS
TRENCH
H.T. SWITCHGEAR
H.T. SWITCHGEAR
FEET 0 1 2 3 4 5 6 7 8 9 10 15 20 25 30 FEET

Fig. 5. GROUND FLOOR PLAN.

The electrical plant installed may be approximated as follows :—

Generating plant having a combined output of	22,000 kw.
Over 50 transformers having a combined output of	31,000 kva.
Over 500 motors having a combined output of	30,000 h.p.
Converters having a combined output of	2,500 kw.

Power Stations.—The principal power station (Fig. 1) is situated at Victoria, and is equipped with four turbo-alternators, two of 2,000 kw. and two of 5,000 kw. A third 5,000 kw. set is in process of completion.

Steam alone is used for power generation, the gas-fired boilers being in close proximity with the generating station, and connected with the main battery of boilers which supplies the blast furnace equipment. While at present some coal is used, it is estimated that, with the completion of the scheme at present in hand, there will be a margin of 10,000 h.p. to 14,000 h.p. available for electrical generating purposes, after the steam requirements of the blast furnaces have been met.

The alternating current is generated at 2,000 volts to 2,200 volts, three-phase, with a periodicity of 50, and the turbines are arranged for a steam pressure of 175 lb., with superheat. The condensing plant is arranged on the "Tinsley" system, plants being driven both electrically and by steam.

Direct current is generated at 250 volts to 275 volts from four high-speed engine sets of about 200 h.p. each, these sets comprising the original installation, and one mixed pressure turbine generating plant, having an output of 600 h.p. The station also contains motor generators for supplying current in bulk to the Ebbw Vale Urban District Council, who utilise the current for lighting and other purposes in the town of the Ebbw Vale and its immediate area. The direct current supply is supplemented to the steelworks area by motor and rotary converters to the extent of 2,500 kw.

possible for the whole of the electrical requirements to be supplied from the main generating station at Victoria. Various considerations, however, come into the scheme, inasmuch as collieries have been acquired in which generating plants were already installed.

It is not necessary to deal in detail with each colliery equipment, beyond mentioning the following :—

Prince of Wales (Victoria) Colliery has an electric winder with gear-driven alternating motor, electrically-driven air compressors, and an electrically-driven variable speed mine fan.

Waunllwyd Colliery has an air compressor installation.

Six Bells Colliery has a mixed turbo-generating plant and a substation dealing with 20,000 volts, 3,000 volts, 2,200 volts and 550 volts.

Abercarn (Prince of Wales) Colliery has a steam-driven turbo-generating plant, and Cwmcarn Colliery has an electrically-driven winder—"Ilgner" system—and an electrical equipment throughout (no steam-raising) plant.

Air Compressors.—Electrically-driven air compressors are installed at the following collieries : Prince of Wales Collieries (Victoria), Waunllwyd Colliery, Marine Colliery, Vivian Colliery.

There are steam-driven compressors at various other collieries.

With the probability of an extended use of compressed air for underground purposes, it is anticipated that a combination of compressors with a regulating set may secure a specially economical working condition in what up to the present is one of the most wasteful and inefficient sources of power.

With this brief outline, it will be at once obvious that various points of view require to be taken into consideration in developing and utilising to the best and most economical advantage the conditions which exist and obtain.

Amongst these are :—

The best utilisation of blast-furnace and coke-oven gases ;

The possible economics and advantages (or otherwise) of the adoption of gas engines ;

The electric driving of rolling mills as against steam driving ;

Electric winding in collieries as against steam winding ;

The total electrification of collieries, already wholly or partially equipped with economical steam plant ;

The generation or purchase of electric power and the extent to which recent legislation and the schemes of the Electrical Commissioners may (or may not) affect developments.

Present-day values of fuel and labour necessitate a revision of hitherto accepted opinions and practice in all the above matters.

A visit to the properties of the Ebbw Vale Company will show to what extent, and in what way each of these problems has so far been dealt with, and also the manner in which provision has been made for the ready adaptation to possible future development, and improved methods and courses, with a minimum of "scrapping."

INTERCRYSTALLINE FRACTURE IN MILD STEEL.*

By WALTER ROSENHAIN, D.Sc., F.R.S., and D. HANSON, M.Sc. (From the National Physical Laboratory.)

IN the course of investigations into the causes of failure and fracture in several hundred articles of mild steel, the authors have found ample confirmation of the general observation that, except at very high temperatures, the fracture of mild steel occurs mainly by the breaking across of ferrite crystals and not by the separation of one crystal from another. This fact has been verified by the systematic examination of fractures, in many cases by the aid of transverse sections cut after the original fractured surface had been embedded in a layer of electro-deposited copper, in accordance with a method devised by one of the authors.† In a small number of exceptional cases, however, distinct evidence of intercrystalline fracture has been obtained. In these cases it is clear from microscopic examination that failure has occurred mainly by the separation of crystals from one another and not by the rupture of the crystals themselves. The exceptional character of these cases, together with the great importance of the failures in question, some of which have had disastrous consequences, lead the authors to present a brief account of them in this paper. Quite apart from any theoretical explanation which may be put forward to account for this exceptional type of fracture, the fact that it can occur under special circumstances is of very great importance to users of mild steel, and particularly to those concerned with high-pressure steam boilers.

The cases in point are as follows :—

CASE I.—*Steel Wrapper Plates from the Combustion Chamber of a Marine Boiler.*‡—The plates examined showed severe cracking around the edges between the rivet-holes. The chemical composition of the steel was normal except that the phosphorus content was somewhat high (0·07 per cent.); it is not, however, suggested that this slightly high phosphorus content has in any way influenced the *intercrystalline* character of the failure in this case. Tensile tests gave normal results for the central portion of this plate, but specimens taken from near the cracked edge showed a low elastic limit and elongation, while notched bar impact tests gave variable and low results. Microscopic examination showed that the cracks were essentially intercrystalline in character, and an example of the type of crack found in this plate is shown in Fig. 1 under a magnification of 500 diameters. The microstructure of the centre of the plate was found to be normal, but near the edges the cementite of the steel, which contained about 0·14 per cent. carbon, was found to be collected in the form of thin layers or films in the boundaries of the ferrite crystals. Lamellar pearlite was present in very small quantities. Fig. 2 illustrates this feature under a magnification of 750 diameters, as seen in a specimen etched with sodium picrate solution.

CASE II.—*Mild Steel Plate, half-inch thick, from the Drum of a Water-tube Boiler.*—This plate also had cracked round the edges, the crack starting from the rivet-holes. This process appears to have continued until the plate was no longer able to withstand the working pressure of the boiler, which at that stage exploded. As in the previous instance, a difference was found to exist between the condition of the material at the centre of the plate and that near the edges. It was, however, less marked than in the previous case. Tensile tests showed no appreciable difference between the central and outside portions of the plate, but notched-bar impact tests gave slightly lower results for the portion near the edges than the centre. The microstructure of the steel near the edges of the plate was also not normal, since the cementite was distributed partly in the form of intercrystalline films and partly as pearlite. In the central portions of the plate the occurrence of massive cementite of this kind was much less marked. The intercrystalline cracks were found to be most numerous in those portions of the plate where there was most free cementite in the crystal boundaries. The microstructure of these parts is shown in Fig. 3 under a magnification of 1,000 diameters, also after etching with sodium picrate.

CASE III.—*Fractured Steel Plates from High-Pressure Marine Boiler.*—The samples of cracked and broken mild steel in this case included the wrapper plate of the boiler itself, two butt straps, and a cover plate. The plates were 1 in. thick, and cracking had occurred around and between the rivet-holes at one of the seams of the boiler where the rivets passed through the wrapper plate, two butt straps, and a cover plate, a thickness of 4 in. in all. It was remarkable that the crack had developed to the greatest extent in the outer cover plate. The outer butt strap was also severely cracked, but the inner strap was much less damaged.

Tensile tests showed no abnormalities in the material notched-bar impact tests, however, were rather variable, some portions of the plates giving good values and others low values. The plates were, however, so severely cracked that it was difficult to select test-pieces in which cracks did not exist, and some portions of the steel were so severely fissured that they appeared to be almost disintegrated. In all cases the cracks were essentially intercrystalline in character, as is illustrated in Figs. 4 and 5, both under a magnification of 200 diameters. These show the same region of the steel before and after etching. Microscopic examination in this case failed to reveal any abnormality in the material of these plates. Normal ferrite-pearlite structure of small size is found in all these samples, which appear to be of satisfactory quality from this point of view.

In the case of this boiler, and in at least one of the others also, it was found that a number of the rivet-heads had sheared off in service. One of these has been examined microscopically, and it has been found that the character of the fracture is the same as in the rivet in the plate itself. The material of the rivet appears to be a mild steel, practically free from carbon. The microstructure of the cracked rivet-head is shown in Fig. 6 under a magnification of 200 diameters.

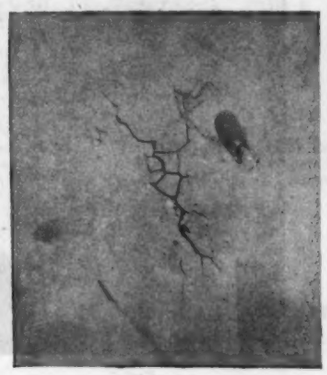


FIG. 1.

Intercrystalline cracks in mild steel boiler plate, not etched. Original magnification ×500.

FIG. 2.

Cementite films in crystal boundaries, etched with hot alkaline sodium picrate solution. Original magnification ×750.

FIG. 3.

Cementite films in crystal boundaries (some pearlite also present), etched with hot alkaline sodium picrate solution. Original magnification ×1000.

In the case of these plates it was thought that the intercrystalline character of the fracture might have arisen from some peculiar weakness in the steel itself, particularly as it has been suggested that once a crack is started in mild steel it may tend to propagate itself along the crystal boundaries. In order to test this point, a special experiment, suggested by Mr. F. S. Tritton, has been carried out. A piece of steel from one of these plates, taken at such a distance from the cracked edge as to insure freedom from actual cracks, was prepared, having the shape and dimensions indicated in Fig. 7. The crooked form of this test-piece and the saw-cut in one side were adopted in order to secure conditions in which, under slow loading, a crack should develop in the steel and gradually spread through it. The loading was stopped at such a point that the resulting crack did not run entirely across the thickness of the metal. Subsequent examination of the cracking shows very clearly that in this case there is no tendency whatever to follow the crystal boundaries. The microscopic appearance of the crack is illustrated in Fig. 8 under a magnification of 200 diameters. It will be seen that a certain amount of distortion has taken place in the steel, and that the crack shows no tendency whatever to assume an intercrystalline character. It should be observed that in this case the loading was very slow, the load being applied gradually at such a rate that the fracture spread half way through the section of the specimen in the course of two hours. The result of this experiment indicates clearly that there is no intercrystalline weakness in this steel, and suggests that in order to produce an intercrystalline crack the stress must operate for a period of years rather than a few hours.

CASE IV.—*Mild Steel Tubing.*—This case of cracking occurred in a piece of mild steel tubing after six months intermittent service without working stresses in a nitre bath working at a temperature of 300 deg. C. The typical appearance of the crack in this case is shown in the micrograph Fig. 9, under a magnification of 150 diameters. These cracks are badly corroded, but their intercrystalline character is unquestionable. The microstructure indicates that the material consists of elongated ferrite crystals and globular cementite. The cementite is not segregated in the crystal boundaries. This structure is commonly found in cold-drawn steel tubing, when the annealing temperature which has been employed between successive passes lies below the Ac1 critical point of the steel. Another sample of steel tubing which had been used for the same purpose, but had not cracked under similar conditions, showed on examination a microstructure corresponding to that of normalised steel.

The character of the cracks in the four cases described

* Paper read before the Iron and Steel Institution, at Cardiff, September 21, 1920.

† W. Rosenhain, Journal of the Iron and Steel Institute, 1906. No. II, page 189.

‡ Board of Trade Report: Departmental Paper, No. 231, 1910.

shows a very striking resemblance to those found under certain conditions in a number of non-ferrous metals and alloys. The most familiar case of this kind is that generally known as "season cracking" in ordinary brass. Case No. IV, described above, shows the closest resemblance to the typical cases of apparently spontaneous cracking in brass, because, in that case, the only stress which can have been operative in producing the crack is an internal stress left in the cold-drawn tube as the result of the drawing operation, since, in that case, no external stresses were applied to the tube. In the case of boiler plates, no actual determination of the amount of stress existing in the material could be made. The steel as supplied in the form of flat plates was probably free from any serious internal stresses, and even the internal stresses set up by the bending of the plates can hardly be held responsible for the failures. In the process of constructing the boiler itself, however, operations are carried out which may easily lead to the establishment of very serious internal stresses. During the process of riveting, if the edges of the plate do not fit together accurately, or if the rivet-holes do not register exactly, the material is forced into position and held there by the rivets. Further, the action of riveting itself may leave considerable stresses in the material in the immediate neighbourhood of the rivet-holes, particularly if the pressure employed in closing the rivet has been very great. In Case No. III the material was in some cases seriously depressed under the rivet-heads, indentations as much as one-sixteenth of an inch below the general surface of the plate being found. The riveting pressure in such cases has been very great and must have left considerable stress both in the material of the plate and in the rivet itself.

In a recent joint paper* with Mr. S. L. Archbutt, F.I.C., one of the present authors has described a number of cases of intercrystalline failure of metals under prolonged application of stress, and has offered an explanation of this phenomenon. In most of the cases described cracking has taken place at atmospheric temperature, but it was suggested in that paper that, for most metals, an increase of temperature would probably facilitate intercrystalline rupture, given the necessary conditions of stress. In many metals, particularly those having a high melting point, it is probable that such failure will only occur at temperatures considerably above that of the atmosphere, unless excessively long periods of time are contemplated. It is therefore of interest to note that the cases described in the present paper in regard to steels have all occurred when the article in question has been exposed for a considerable period to a slightly elevated temperature. Up to the present time the authors have not observed a fracture of this kind which has occurred in a steel article which has been exposed to stress at the ordinary temperature only.

Some cases of intercrystalline fracture having a considerable similarity to those here described, and also occurring in a metal having a high melting point, have been described by H. S. Rawdon and A. I. Krynitsky.† These occurred in the nickel electrodes of sparking plugs, where intercrystalline cracks developed during use. Rawdon and Krynitsky concluded that the relatively low stresses due to the differential expansion of the shell and the electrode were sufficient to cause fracture of the hot wire by the formation of intercrystalline cracks, and that, while other causes might have an influence, this factor was the chief cause of failure. In nickel also, therefore, under correct conditions of stress and temperature, gradual intercrystalline failure may occur.

Attention must also be called to another factor which is known to accelerate intercrystalline cracking in many metals and alloys. This is the effect of corrosion, whether caused by circumstances arising in the normal use of the article, or intentionally brought about, as, for instance, by the action of solutions of mercury salts on brass. This accelerating action of corrosion appears to be due to the fact that the intercrystalline material, whatever its nature, is first affected by corrosive influences, with the result that the cohesion between crystals is rapidly weakened where such attack occurs. As it has been clearly proved that corrosive action is not essential to the occurrence of intercrystalline cracking under the prolonged application of stress, this action can only be regarded as a subsidiary and not a fundamental cause of the phenomena. At the same time it is desirable to point out that in the four cases of intercrystalline cracking in steel which have been described in this paper, corrosive influences have been at work. In the case of No. IV, definite corrosion of the cracks is visible under the microscope. In the case of the various boiler plates also there are indications that corrosion has occurred, although it is not clear whether this action took place before the cracks were formed or after they were formed as the result of consequent leakage. The formation and development of these intercrystalline cracks may, therefore, have been accelerated by corrosive action. The suggestion has been put forward that cracking of this kind, and particularly the shearing of rivet-heads, may be due mainly to the presence of an excessive amount of soda in the boiler water. It is suggested that liquid containing soda may penetrate between the plates and rivets, and that subsequent carbonisation of the deposited material may lead to an increase of volume and consequent occurrence of very powerful stresses. In the present authors' opinion, however, such an action can scarcely have contributed to the failure of the plates in question. In the first place there is nothing whatever to indicate why the stresses set up in such a manner should produce intercrystalline failure without serious deformation of the steel, instead of the usual plastic deformation which would allow the steel to accommodate itself to the slight increase of volume in the deposited material. In fact, it may well be asked why the occurrence of such a deposit and its subsequent expansion should produce intercrystalline cracking rather than a slight amount of ordinary stretching in a material which possesses very considerable ductility.

In presenting the above account of a few remarkable cases of intercrystalline fracture, the main object of the authors has been to call attention to the fact that failure of this kind is possible in certain structures, even when material of good quality is used in their construction. They have in mind particularly the high-pressure steam boilers, in which most of these cases have been observed. In view of the modern tendency to increase pressures and temperatures, the question is one of very considerable importance. Higher pressures imply not only higher temperatures, but thicker boiler plates and greater difficulty in fitting and consequently higher pressure in riveting. All of these factors tend to increase the liability to produce severe internal stresses in the material of the finished structure.

With regard to the quality of the material itself, the authors had at one time hoped that properly normalised steel would not fail in this manner in the ordinary lifetime of a steam boiler. In the first three cases of failure of this type which came under their notice, the material in the neighbourhood of the crack did not possess a normalised structure. In two cases, both of them boiler plates, the edges of the plates had been exposed to heat treatment such that the cementite had become massed between the ferrite crystals, while in another case (No. IV, above) the cementite existed as small globules, generally scattered through the ferrite crystals. Case No. III, however, left no doubt that material apparently of good quality could undergo failure of this kind. It seems very probable, however, that undesirable thermal treatment may, to an appreciable extent, facilitate intercrystalline cracking. The whole matter is one which obviously requires much further investigation.

For this purpose, in addition to laboratory experiments, the systematic and exhaustive examination of every case of cracking in boiler plate steel would be of very special value.

FIG. 4.

Intercrystalline cracks in mild steel boiler plate, not etched. Original magnification ×200.

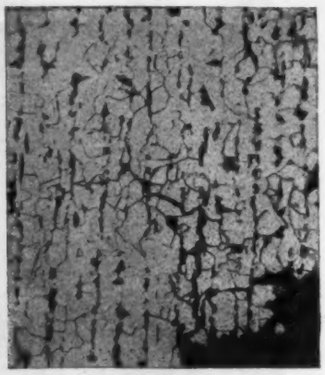


FIG. 5.

Same section as Fig. 4, after etching with 1 per cent. nitric acid in alcohol. Original magnification ×200.

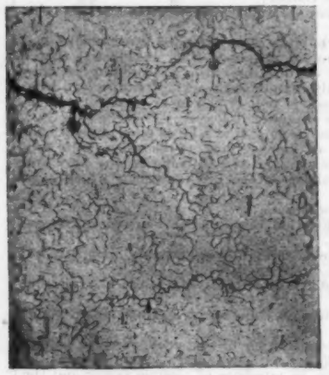
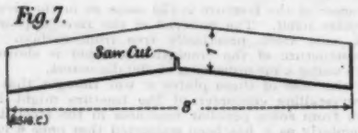


FIG. 6.

Intercrystalline cracks in mild steel rivet head, etched with 1 per cent. nitric acid in alcohol. Original magnification ×200.

(Reduced by one-quarter.)

Fig. 7.



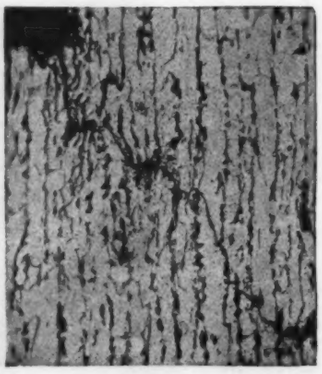


FIG. 8.

Crack running through crystals in slowly fractured mild steel test piece, etched with 1 per cent. nitric acid in alcohol. Original magnification ×200.

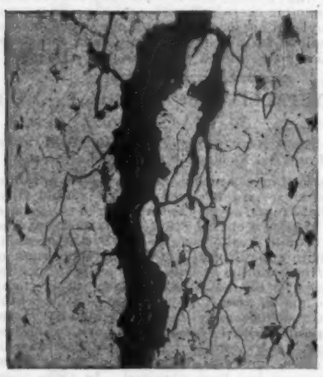


FIG. 9.

Spontaneous intercrystalline cracks in cold-worked mild steel tubing, etched with 1 per cent. nitric acid in alcohol. Magnified 150 diameters.

(Reduced by one-quarter.)

* Rosenhain and Archbutt, Proceedings of the Royal Society, 1919 Vol. xcvi, page 556.

† Rawdon and Krynitsky, Bulletin of the American Institute of Mining and Metallurgical Engineers, 1919, No. 152, page 1323.

SERVICE EXPERIENCE WITH CONDENSERS.*

By Engineer Lieutenant-Commander G. B. ALLEN, R.N., Member.

THE importance of the elimination of condenser defects has been recognised in the Navy for many years, and as this question is assuming an increasing degree of prominence in the mercantile marine and land installations, it is hoped that some remarks on service experience may be of interest and some value.

In the early days of low powers and comparatively high ratio of machinery weight in war vessels, a high standard of purity of feed-water was not absolutely essential, and owing to its protective qualities a certain amount of boiler scale was not particularly objectionable. Under these circumstances the boilers were frequently worked with a slight density, and the admission of small amounts of salt water to the feed was a matter of no great moment, and indeed would not ordinarily be detected.

Further developments in the direction of greater horse-power per unit weight of machinery required the attainment of the maximum boiler efficiency compatible with the type of boiler then employed, and the presence of any non-conducting scale upon the heating surfaces could no longer be tolerated. A high standard of purity of feed therefore became essential, and condenser defects, hitherto unnoticed, became more and more apparent. Subsequently the demands for maximum power on a minimum weight necessitated the development of the water-tube boiler, which in its present form is peculiarly sensitive to the quality of feed supplied, and a condenser defect which formerly would have been regarded as of little importance is now attended by results which are out of all proportion to the magnitude of the defect itself.

Among the immediate results following upon such a defect as a small perforation are :—

(*a*) A rise in the density of the boiler water followed by priming (*i.e.*, the passage of water with the steam through the system), with consequent possible damage to fast-running reciprocating auxiliaries, and undue wear (erosion) of turbine nozzles in modern vessels; and unless the evaporation is considerably eased, and the engines either slowed down or stopped, the mechanical damage caused by the water passed over may be very considerable.

(*b*) The deposition of scale upon the heating surfaces.

(*c*) The commencement of serious corrosive action in the system, including both boilers and turbines, the first-named being particularly severe in the highly forced boilers of the present day.

It is on these grounds, both of reliability and durability, that the importance of maintaining a pure "feed" rests.

Fortunately, the proportion of defective tubes compared with the number of tubes on service is extremely low and is not greater than 50 in 1,000,000 per annum; but if it be realised that in a large vessel fitted with some 48,000 tubes of a total length approximating to 115 miles, such a small defect as a $\frac{1}{4}$ in. diameter per hole or one cracked tube may render the vessel unmanageable in a moment of great stress, it will be evident that it is a matter of great importance to secure immunity from such defects, and, moreover, one which requires considerable investigation and joint co-operation between the manufacturer, the metallurgist and the user.

Many of the early difficulties experienced were found to be due to faulty design and manufacture, but these, which concerned accuracy of fitting rather than faults in the tubes themselves, have been gradually eliminated. Defects of this nature may be summarised as follows: (1) Insufficient support of tubes between the tube plates; (2) holes in diaphragm plates too large; (3) holes in tube plates too large or too small; (4) unsuitable packing; (5) slackness of ferrules in tube plates; (6) steam or drain orifices unsuitably placed, allowing steam and hot water, sometimes contaminated with oils, to impinge on certain tubes.

Insufficient support led to undue vibration of the tubes, and although this has been largely rectified by the provision of suitable and unequally-spaced diaphragm plates, and by limiting the diameters of the tubes and the holes through which they pass, a certain clearance must of necessity be allowed; and the effect of vibration, more especially in high-speed vessels, cannot be ignored.

Experience has shown the necessity of adhering to rigidly-defined limits in regard to the tolerances of tubes and holes in tube plates, both on the score of guarding against the fit being too close, with consequent abnormal strain thrown on the tubes when screwing up the glands, and also of guarding against too loose a fit, resulting in the packing being forced between tube and tube plate and probable leakage. Similarly, the exact concentricity of ferrules and tubes within narrow limits is of importance. Since the adoption of limiting clearances, defects of this character have to all intents and purposes been eliminated.

Opinions concerning the suitability of packing materials vary, and outside the service there appears to be little uniformity of practice. Experience in naval vessels shows that the linen gromet made to present Admiralty specification gives every satisfaction, and with ferrules and their stuffing-boxes screwed to correct gauge, difficulties due to gland leakage may be regarded as having been coped with successfully.

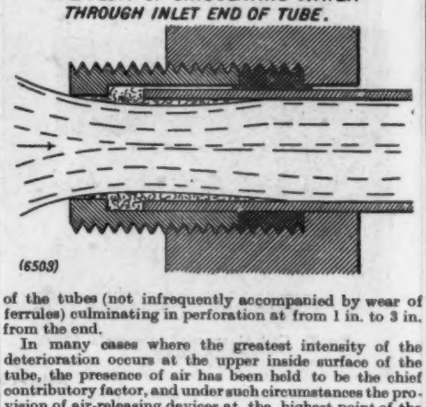
Investigations into the general problem of the nature of the underlying causes of corrosion within the alloy itself have resulted in various theories, none of which have as yet met with general acceptance, and in the present stage the most we are able to do is to endeavour to trace each defect to its immediate observable source. In many cases this is possible and a fairly simple matter; but in others, such as may be covered by the description "general corrosion," considerable difficulty may be experienced. Fortunately such cases are comparatively few, and though it may be argued that this comparative freedom hardly justifies the necessary expense and trouble of further investigation, yet from naval considerations it is just these few cases for which remedy must be found.

The information available at the Admiralty is derived from reports forwarded by ships as failures occur. Owing to the conditions of service during hostilities it has been impossible to obtain complete records of all failures during that period, but from examination of reports received since the cessation of hostilities, the following statement has been deduced to show the present causes of failure in the proportion in which they have occurred :—

	Per Cent. of Total Failures.
(*a*) Deterioration at inlet ends ...	18·0
(*b*) Perforation due to local pitting ...	14·8
(*c*) Perforation due to obstruction ...	14·8
(*d*) Perforation due to steam impingement	5·4
(*e*) Crushed ends	5·4
(*f*) Splitting	10·8
(*g*) Perforation due to contaminated circulating water	1·0
(*h*) General corrosion	29·8

The large proportion of failures due to deterioration at the inlet ends of the tubes is noteworthy. Generally speaking, there is a marked thinning away at the ends

THE FLOW OF CIRCULATING WATER THROUGH INLET END OF TUBE.



(6503)

of the tubes (not infrequently accompanied by wear of ferrules) culminating in perforation at from 1 in. to 3 in. from the end.

In many cases where the greatest intensity of the deterioration occurs at the upper inside surface of the tube, the presence of air has been held to be the chief contributory factor, and under such circumstances the provision of air-releasing devices at the highest point of the circulating water system has proved of marked benefit. However, with all such mechanical precautions, the evacuation (before entry to the tubes) of air which is necessarily in suspension in the circulating water is at the best only partial. This is more especially the case in high-speed shallow-draught vessels, and as will be evident from an examination of Fig. 1, the sharp edges both of ferrule and tube, assisted to some extent by the possibility that the tube and ferrule may not always lie perfectly concentrically, tend to break the flow of water and to form pockets of an unstable nature where air may be reasonably expected to accumulate.

This type of defect has been particularly noticeable in vessels serving in shallow waters containing a considerable proportion of solid matter, *e.g.*, sand, chalk, &c., and this, together with the comparatively high-water velocity through the tubes, points to the influence of erosion, or the abrasive action of gritty particles, as being of considerable importance. The presence of such gritty matter cannot of course be avoided on service, and it appears that investigations with regard to the elimination of this type of defect must take the lines of endeavouring to obtain a metal whose surface is better able to withstand this abrasive action.

Whereas in the cases of tube-end deterioration the number of tubes affected in any condenser (apart from those which actually fail) may be considerable; cases of local pitting are rarely evident in more than one or two tubes in the condenser concerned, and when once a failure has occurred and the tube plugged or replaced, little further trouble is experienced. In these cases perforation occurs at isolated spots, and the failure has been generally considered to be due to some local defect, *e.g.*, a spill or lamination. To quote the author of a previous paper on this subject, "The importance of spills cannot be exaggerated,"* and the elimination of defects of this character is entirely a question of the manufacture of the mechanically perfect tube, which desirable result can only be obtained by the drawing down of a mechanically perfect cast shell. The practice of turning and boring each shell, even if regarded as merely for purposes of exploration of the metal immediately beneath the surface skins, has a considerable safeguarding effect toward the reduction in the number of such surface irregularities, as may be discovered on sighting.

Perforations, the cause of which has been directly traced to obstructions, were particularly prevalent in coal-burning ships where the ashes were discharged beneath the water-line, and though it is possible to nullify the effect of a vessel's own refuse by suitably placing the ash shoots and by the adoption of oil-fuel firing, yet such obstruction of tubes by cinders, &c., may still be caused by refuse from other vessels.

The recorded cases where failure has occurred through the impingement of steam and water directly on a limited area of the outer surface of certain tubes are few, and in general have been confined to condensers other than those of Admiralty design. Such failures should not occur, provided that orifices are suitably placed and baffled.

The proportionate number of failures due to crushing is small, and these may be regarded as isolated cases. In no case has it been established that over-tightening of screwed glands has been resorted to, and the fact that crushing sometimes does occur, serves to emphasise the importance of the tubes being sufficiently hard to stand a reasonable margin of pressure due to tightening up above that absolutely necessary to secure watertightness, though it may be remarked that crushing is sometimes observed as a natural result of the weakening of tubes which have been attacked internally by corrosion of a general nature.

There is some divergence of opinion as concerning the most desirable degree of purity of the 70 : 29 : 1 alloy, but investigation has shown that a large proportion of the tubes which have failed from splitting have been manufactured from materials of a lower standard of purity than that required by the Admiralty specification.

Apart from the question of purity of constituents, the internal condition of stress in the finished tube must have considerable bearing on the liability to season cracking and splitting. The work done during the final draw (which must be such as to leave the tubes sufficiently hard to stand the test of grometing) of necessity leaves the material of the tube in an indeterminate condition of internal stress, and anything that can be done which will eliminate this internal stress, while at the same time allowing the tube to retain the requisite hardness, will be of great benefit in minimising defects from this source.

The case in which failure has been directly ascribed to the use of unsatisfactory circulating water is exceptidnal, but it certainly gives weight to a widely-held opinion that the conditions under which many condensers are worked in the early stages of their life (*e.g.*, in comparatively stagnant fitting-out basins contaminated by various kinds of refuse) are conceivably of importance as a primary cause of tube decay. On the occasion referred to the vessel had been anchored in waters contaminated by sewage, and the case is quoted as emphasising that materials for marine usage should be able to resist corrosion under varying conditions which do not allow of the selection of particular materials to suit particular waters. The deleterious effect of vegetable oils has already been described before this Institute,* but the writer is not aware of any experiments having been carried out to determine the effect of oil fuel in regard to the acceleration of corrosion; though it may be remarked that in one of H.M. vessels which reported a considerable number of defective tubes within two months of entering into service, no definite cause could be traced beyond that extended basin trials had been carried out in comparatively stagnant water contaminated by a considerable leak from one of the ship's tanks.

The proportionate number of recorded failures due to general corrosion does not adequately express the importance of this class, these being cases of actual failure only, *i.e.*, general corrosion culminating in perforation; whereas the great majority of cases in which general corrosion is present are not recorded, and it is the possibility of failure at an unknown moment which gives this matter so serious an aspect.

Leakage from electric circuits has been put forward as being a contributory cause of corrosion, but though no evidence of a positive character has been obtained in support of this contention, it has been observed that failures have occurred shortly after the discovery of "earths," and it is probable that the effect, if any, is one of acceleration rather than a primary cause.

The general problem of corrosion of condenser tubes may be conveniently regarded from four different standpoints: (1) The arrest or prevention of corrosion in condensers as at present constructed; (2) the treatment of tubes of accepted composition; (3) the general design of condensers; (4) the utilisation of more suitable alloys than those at present in use.

The provision of steel protector plates and cast-iron water ends has proved satisfactory in checking the rate of deterioration provided that good connections are secured, but at the same time considerable wear of the cast-iron ends takes place, and this wear if excessive is a very undesirable feature. The present Admiralty practice is to make the tubes and tube plates of as nearly the same composition as is practicable and to secure steel slabs direct to the tube plates, but from the foregoing remarks it cannot be said that this practice is entirely effective.

The Cumberland process has been fitted in certain vessels, but beyond the fact that it has been found that this process has not arrested decay where such decay has been in evidence before the process has been installed, the experience gained has not been sufficient to allow of any reliable conclusions being drawn.

With regard to the treatment of working tubes, the

* Paper read before the Institute of Metals, at Barrow-in-Furness, on September 16.

* Bruhl, Journal of the Institute of Metals, 1911, vol. vi, page 304.

* Bruhl, Journal of the Institute of Metals, 1911, vol. vi, page 291.

Admiralty (acting on a well-known and successful practice of coating corroded copper pipes with a film of pitch and marine glue) have experimented with resistant varnishes. In the first vessel treated, although a certain degree of protection was obtained, it was found that, probably as a result of the erosive action of the water (but possibly on account of the difficulty of forming a film of even thickness and of satisfactory drying), the varnish became washed away in places, thus exposing portions of the bare metallic surface to the action of the water. Experience with a second vessel has not been extensive, but it is understood that general corrosion which formerly resulted in comparatively frequent failures has been entirely arrested. In these cases the varnish has been applied to the tubes "in place" and dried by the admission of steam to the condenser, and it is probable that such a process carried out on tubes before being fitted would be of considerable value, provided that the surfaces formed withstand the work of fitting in place and prove sufficiently resistant to abrasive influences.

The protective value of an oxide film has been suggested by a former report of the Corrosion Committee, and the Admiralty have under observation a vessel fitted with tubes on which such a film has been formed; unfortunately this vessel has done very little steaming and no useful data have as yet been obtained.

In regard to the elimination of failures caused by surface defects, *e.g.*, spills, a vessel has been fitted with compound tubes made on the lines suggested by Sir Charles Parsons,* but here again owing to post-war conditions it has not been possible to obtain any conclusive results.

The general design of condensers has been found to be closely connected with tube defects, or rather with the acceleration of deterioration, and in particular in regard to certain designs where the whole of the tubes are not drowned. In these designs a few of the upper rows of tubes which are situated above the water-line have been observed to be particularly prone to corroaive action, and consequent upon the general thinning this action is not infrequently accompanied by "end crushing." Generally speaking, the design must of necessity be prepared with regard to the space and position available in the ship, and under the present conditions the approximately horizontal position must be accepted as inevitable. In very early designs vertical tubes have been employed, but in such cases where it has been necessary to arrange for outside circulation the lower surfaces of the tubes have been found liable to deterioration. The present practice is to allow the circulating water to pass through the tubes, and it may be noted that the alternative method of outside circulation not only does not lend itself to a suitable engine-room arrangement, but is undesirable on account of the difficulty of providing access for cleaning.

The Admiralty have from time to time experimented with tubes of various compositions, but experience to date has shown that the tubes made to Admiralty specification have proved the most satisfactory under the varying conditions imposed by naval service. With every precaution taken during manufacture, and with the adoption of any known preventive or protective process, it must be admitted that freedom from deterioration cannot be guaranteed, and it appears that complete immunity, or at least a guaranteed life, can only be obtained by the employment of an alloy other than a simple brass.

CRYSTAL GROWTH AND RECRYSTALLISATION IN METALS.†

By Professor H. C. H. CARPENTER, M.A., Ph.D., A.R.S.M., F.R.S., Past-President (London), and Miss C. F. ELAM, Member (London).

(*Continued from page* 389.)

THE conclusions drawn by the authors from a large number of observations may be summarised as follows:—(1) growth may take place either of a large crystal into a smaller one, or of a small into a larger, i.e., crystal growth does not depend upon the relative size of the crystals; (2) the relative orientation of the crystal which is being grown into and that which is growing does not appear to affect growth; (3) a crystal which is itself being invaded by one crystal may grow at the same time at the expense of another; (4) the rate of growth is not constant for any given time at any particular temperature; (5) the change of orientation is accompanied by a difference of level of the surface, which is the boundary marking observed.

After reference to the work of Ewing and Rosenhain, the authors stated that the difficulty of finding a suitable method of testing whether the crystals of castings do or do not grow is considerable. In the first place, all form of strain in cutting, grinding, and polishing a specimen must be avoided, because it is known that work will produce recrystallisation of a metal on annealing. The ordinary methods of cutting, grinding, and polishing are quite sufficient to cause recrystallisation of the surface layer on heating. This is particularly noticeable in soft metals. It is frequently found that after annealing cast a brass or copper twins are formed, and these are due entirely to the strain set up by cutting, filing, &c. Lead, zinc, and tin are still more difficult to examine in the cast state, owing to the spontaneous recrystallisation of these metals after work. It was therefore considered inadmissible to polish and etch a casting, photograph an area, and to heat and examine the same area again, because any change in the marked area might easily be ascribed to the effect of annealing after work. If sufficient of the metal were removed after annealing to ensure that all the affected region was taken away, the area marked would also be removed and the test would be quite indecisive. Some experiments were carried out with both tin and lead by casting on plate glass, so as to obtain a smooth surface which had not been worked in any way. Although the results obtained indicated that there was no growth of the crystals on heating, yet the evidence obtained was not sufficiently convincing and was open to several objections. The deep etching required after annealing to ensure that all the previous etching had been removed, roughened the surface and obscured any very small changes that might have taken place. Or if any very small changes were observed they might easily be attributed to the fact that the deep etching had removed the original surface layer and had substituted a second which was slightly different. Alloys cannot be used in the cast state, since they are generally cored, and the coring obscures the crystal boundaries. It is also necessary to avoid any metal or alloy which undergoes a phase change on heating.

The method finally adopted was suggested by the well-known fact that impurities tend to lie in the crystal boundaries of castings, whereas in the worked and annealed metal they either pass into solution or remain scattered throughout the crystals quite independently of the boundaries. It was thought that if it could be shown that after prolonged annealing the boundaries coincided with the impurities, it might be considered evidence that the boundaries were in the same position after annealing as before it. The impurities must be such that they are insoluble in the metal and have a high melting point. If the annealing temperature were higher than the melting point, a growing crystal could easily push the molten impurity in front of it. Iron, which is present in even the purest aluminium, exists in the form of a compound, $FeAl_3$. It has a melting point very little below that of aluminium, and is insoluble in the aluminium even after prolonged annealing. The aluminium used in these experiments contained 0·17 per cent. iron and also 0·22 per cent. silicon, but the latter is soluble. In the metal as cast, some of this compound is always found existing in the boundaries, although some is distributed within the crystals. A photograph of cast and annealed aluminium is given (Fig. 25), and shows that even after annealing for ten weeks at 550° C. the boundaries are still outlined by the impurities. Since the latter cannot have moved, it follows that neither have the boundaries. If insufficient of the surface layer were removed after annealing, a movement of the crystal boundaries relative to the impurities was always observed. The photograph of the cast and annealed aluminium should be compared with one of a part of the same casting rolled and annealed for the same period (Fig. 26). Except in a few places the boundaries are seen to be quite free from impurities, and this is typical of all worked metals containing impurities examined by the authors.

DIAGRAM No 7

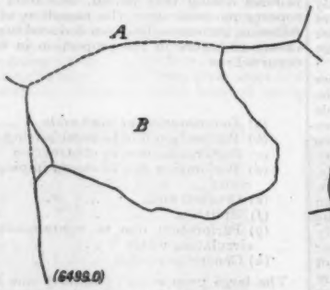
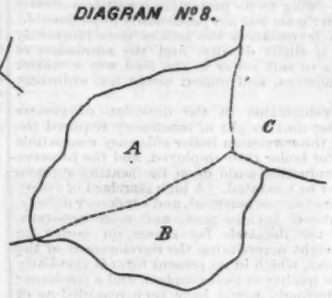


DIAGRAM No 8.



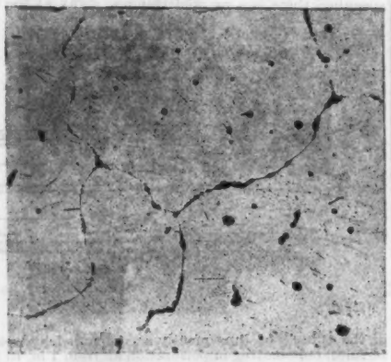


FIG. 25. Cast Al. annealed 10 weeks at 550° C. × 100.

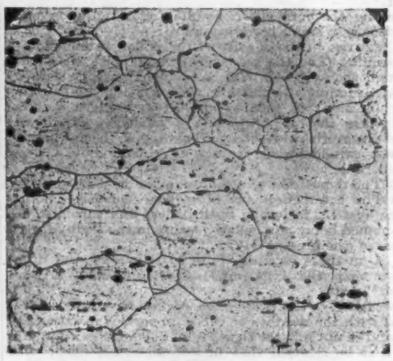


FIG. 26. Same rolled and annealed 10 weeks at 550° C. × 100.

Reduced by one-sixth.

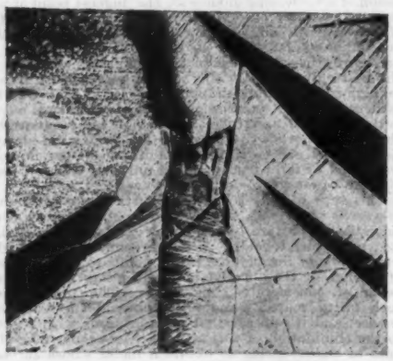


FIG. 27. Twins and Slip Bands produced by work in Sb–Sn alloy. × 100.

Reduced by one-sixth.

If it is a fact that a cast metal free from strain shows neither crystal growth nor recrystallisation on subsequent heating, whereas after it has been worked it shows either or both of these phenomena, then it follows that deformation is alone responsible for growth. The temperature and the time of annealing, however, affect the results of the deformation, and reference must always be made to them in this connection. Mathewson and Phillips showed very clearly how different results were obtained by heating metal which had the same percentage deformation, to different temperatures. Similarly, it has been found in all the experiments now to be described that the temperature of annealing, subsequent to the work, determines within limits what results will be obtained. Time is also a factor to be taken into consideration unless it is eliminated by heating until no further changes take place. This method was adopted in most of the experiments, so as to determine the relationship between the effects produced by deformation and subsequent heat treatment.

It has been found in the experiments now to be described that the effects of work followed by annealing can be divided into three categories, according to the degree of deformation:—(1) Slip-bands or twins, or both, may be produced, giving a certain permanent deformation, but on annealing they are reabsorbed without further change. The effect of the deformation is only permanent in so far as the metal has undergone a slight change in shape; (2) growth of some of the existing crystals may take place. For this a further amount of deformation than (1) is required; (3) recrystallisation may occur. This is always followed by crystal growth if sufficient time be given. All deformation beyond a certain fixed amount gives this result.

The amount of deformation required to produce the

* Journal of the Institute of Metals, 1911, vol. vi, page 305.

† Abstract of a paper read before the Institute of Metals, at Barrow-in-Furness, on September 15.

above results varies with the subsequent annealing temperatures.

1. The effects of slight deformation will be dealt with first. The first experiments were carried out with the antimony-tin alloy. It was thought that owing to its peculiar property of showing the new crystal boundaries by heating alone, any very small change would be quickly noticed. A specimen was used which had been heated until no further change took place. This was repolished and heated once to be sure the polishing had not stimulated growth, and was then squeezed gently in the vice. Twins were formed first of all, and were similar to those found by Edwards in pure tin, and the metal emitted the well-known tin "cry." Slip-bands were not numerous, and were confined to the more severely strained region. Fig. 27 shows the formation of both twins and slip-bands. On heating, this specimen at 200 deg. C. no change was observed in the boundaries, nor was there any recrystallisation. On repolishing and re-etching it was noticed that some of the twins had disappeared, having apparently returned to the original orientation of the crystal. Others, however, persisted. It is interesting to note with regard to the effects of slight deformation, that Mathewson and Phillips found that they could strain a brass until bands were developed all over the surface, yet on annealing there was no visible change in the shape or character of the crystals, except that the slip-bands disappeared. It should, however, be remembered that repolishing a surface after straining always removes slip-bands which are surface markings. Such a method has indeed been used as a means of distinguishing between slip-bands and twins. Twins reappear on etching. It is noticeable in this alloy that twins are regularly formed by straining but frequently disappear after annealing, and if the metal has recrystallised after work they are never found. The slip-bands naturally disappear after this treatment.

2. The same specimen after being heated so as to be sure that no further change took place, was squeezed again until the surface was considerably roughened. Twins and slip-bands were then found in large numbers. On heating, new crystal boundaries appeared in a few places, indicating that the crystals were growing. After heating four times all change had ceased. Fig. 28 shows the boundary markings produced in one area. The twins have tarnished and hide the markings to some extent. On repolishing and re-etching, the structure as shown in Fig. 29, was obtained. A diagram (No. 7) has also been prepared to explain more easily what has taken place. The dotted line represents the original boundary of the crystal marked A. This crystal has grown to the extent of the full line, and has added to itself the area marked B. It will be noticed that the new boundaries are rather jagged in outline. Another example is given in Figs. 30 and 31. Fig. 30 is the appearance after heating four times. Fig. 31 is of the same area repolished and re-etched. Diagram No. 8 shows the original boundaries as dotted lines and the final boundaries as full lines. It appeared at first as if a small crystal was forming in the boundary between A and B. On repolishing and re-etching, however, the part enclosed by the outermost marking was found to be all of one orientation, which was the same as that of the dark crystal C. In this case C has grown into both A and B, and all the boundaries between A and B, A and C, and B and C, had disappeared. The appearances of the twins in the photographs before and after etching are rather misleading, but it must be remembered that in the former (Figs. 28 and 30) they are represented as differences of level only and a slight tendency to tarnish differently, whereas in the latter (Figs. 29 and 31) they are revealed by their different behaviour towards the etching reagent. These examples are two of many instances of movement of the crystal boundaries produced on heating after the metal had been slightly strained. In every case there was actual growth of already existing crystals without previous recrystallisation. It was often noticed that polishing alone was sufficient to stimulate growth which had ceased indicating that considerable work must be done on the surface layer during this process.

3. Squeezing a specimen of this alloy more violently produces complete recrystallisation on annealing. Owing to the unevenness of the surface it is not possible to give photographs illustrating this point in the same way as with slighter deformations, but the effect of severe work is shown in the two following photographs (Figs. 32 and 33). A specimen in which all growth had ceased was scratched by a needle and annealed. Fig. 32 shows the scratch crossing the boundary between a light and a dark crystal. The new crystals on either side of the scratch can be seen. In the dark crystal some of them are white, showing that they are small crystals of different orientation from that of the original dark crystal. Similarly, some in the white crystal appear dark. Fig. 33 shows the end of a scratch in a dark crystal. The crystals formed round this scratch are larger than those in Fig. 32, because it is broader and deeper. All the crystals shown in the photograph are new ones formed as a result of the scratch, except the dark background, which is part of the original crystal. Except in the immediate neighbourhood of the scratches, there was no change in the specimen. This indicates very clearly the role played by plastic deformation in causing recrystallisation. It has already been pointed out that the ordinary methods of cutting and grinding cause recrystallisation of the surface layer. How far these effects penetrate it is difficult to say. Certainly after grinding a considerable amount of metal has to be removed before it is possible to observe its unaltered structure underneath.

FIG. 28.

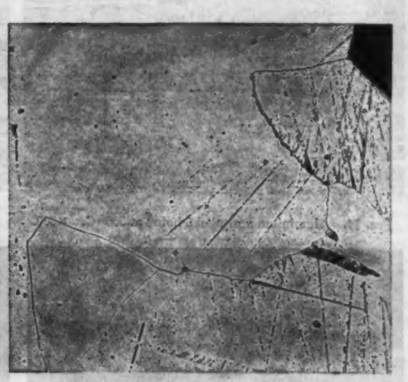


FIG. 29. Same as Fig. 28, repolished.

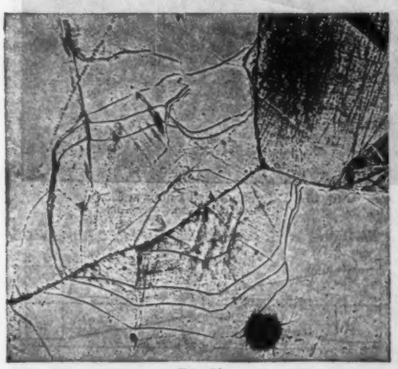


FIG. 30.

FIG. 31. Same as Fig. 30, repolished.

FIG. 32. Recrystallisation round scratch.

FIG. 33. Recrystallisation round scratch.

Magnification 75 diams. Reduced by one-sixth.

It was laid down at the beginning of this paper that in the authors' view the essential difference between growth and recrystallisation is that the latter originates from new centres, whereas growth occurs simply at the expense of already existing crystals. Chappell found that recrystallisation began with the formation of minute crystals in the boundaries of the old distorted ones. All his work was done on iron, but Mathewson and Phillips have shown that the same thing occurs in the early stages of recrystallisation of brass. This has also been confirmed by the authors in the case of aluminium. Recrystallisation is very rapid from 350 deg. C. upwards, but at lower temperatures the process can be studied more easily as it is considerably slower. A photograph is given of the purest aluminium sheet (99·6 per cent. aluminium) which has been annealed at 300 deg. C. for three hours. At the end of this time small new crystals made their first appearance, and two of these are shown (Fig. 34). They appear white in contrast to the unoriented material, which has a granular appearance. This contrast between the old and new crystals is very marked during recrystallisation, until all the former have been absorbed by the latter. Another specimen annealed for seven hours at 300 deg. C shows how the new crystals have increased both in number and size (Fig. 35). A photograph of fully annealed aluminium has already been shown in Fig. 26. Recrystallisation took place in this way in all the specimens examined. It began from comparatively few centres, and gradually the small crystals increased in size and in number.

The only theory of recrystallisation that has been put forward is that enunicated by Mathewson and Phillips, and supported by Howe and Jeffries. It assumes that (1) inner surfaces are formed in the crystal in the process of slip due to work; (2) work destroys the uniformity of orientation of a crystal. Without entering into a discussion of this theory, the following points should be taken into consideration in connection with it; (1) There is no evidence known to the authors that recrystallisation takes place by a process of disintegration of the crystal. On the contrary, all the evidence available is against this. Recrystallisation begins from a few centres in the old crystal boundaries; (2) there is no evidence known to the authors that after deformation the orientation of a crystal differs in any way throughout its extent. Etching pits are as yet the only real guide to specific orientation, and even in severely worked material they are constant for any given crystal; (3) Mathewson and Phillips themselves admit that recrystallisation is frequently brought about on annealing although no inner surfaces, i.e., "etch-bands," had been visible beforehand.

The previous experiments have only been qualitative in character. After it had been shown that the crystals of a metal will either grow or recrystallise, or both, according to the amount of deformation, it was desired to determine the exact amount of deformation required to produce these effects. Following the example of Chappell, &c., tapered test-pieces were cut from a strip of a brass ¼-in. thick. The size and shape of the test-pieces are shown in Diagram No. 9. The first test-piece was annealed at 750 deg. C. for one hour, and then the whole of one surface was polished. By polishing the surface before pulling the limit of strain is shown by the point at which the slip-bands cease. The test-piece was not broken, but was pulled until about half of the surface was roughened by the appearance of slip-bands. Each half of the test-piece then represented material ranging from quite unstressed crystals to those in the thinnest part which were considerably distorted. The appearance of the strained surface was interesting, and showed very clearly how differently oriented crystals

had strained to different degrees according to their positions relative to the applied stress. The test-piece was cut across the thinnest part, and one-half was annealed at 750 deg. C. for one hour. A large area of moderately-sized crystals was found between the smaller crystals in the thin end and the unaltered crystals in the thick end. This was contrary to what was found by Chappell and Hanson, who showed that in similar experiments a band of large crystals was formed confined to a relatively small area. The difference in the results obtained by the authors was no doubt due to the very uneven straining of the individual crystals, so that some were probably unaltered, while others grew and yet others recrystallised and grew. In order to reduce these internal strain gradients to a minimum, another test-piece was annealed at 550 deg. C. for one hour so as to obtain much smaller crystals.

The test-piece was polished and pulled as before. It was then cut in half and each half cut again longitudinally, so that there were four equal sized pieces, each having a thin and thick end corresponding to the stressed and unstressed regions. One part was kept to show the position of the yield point, while of the other portions, one was annealed at 750 deg. C. and the other at 550 deg. C. for one hour. The fourth was used in an experiment to be described later. The piece annealed at 750 deg. C. developed a band of large crystals at some distance from the thin (stressed) end. They did not, however, reach as far as the limit of stress, as shown by the absence of slip-bands in the unannealed portion. A photograph of this piece is given natural size, and the yield point is marked by a line across the specimen (Fig. 36). In the second portion annealed at 550 deg. C. larger crystals were also produced in one part, but nearer to the strained region than in the piece which was annealed at 750 deg. C. There was apparently no change in the crystals lying between the large crystals and the limit of stress (Fig. 37).

In order to discover, if possible, exactly how these large crystals are formed, the fourth and last part of the test-piece was annealed for only 15 minutes at 750 deg. C. The point at which the large crystals developed at this temperature was already known from the preceding experiment. An examination of this region showed the crystals to be very variable in size; some of them were the same as those of the original sheet, while others were much larger (Fig. 38). This is very distinct evidence that the larger crystals are those that eventually become the comparatively enormous crystals between the regions of recrystallised and unaltered crystals. The fact also that they are associated in their early stages with crystals of the same size as the original unstrained crystals suggests that they are formed directly from these without a preliminary refining due to recrystallisation, i.e., by growth of the original crystals.

It has already been shown by means of experiments with the antimony-tin alloy that growth of the original crystals can take place directly without previous recrystallisation. It is therefore possible to divide this tapered test-piece into three regions, according to the effects of annealing after straining:—(1) The region where strain was least, which showed slip-bands, but where there was no change on annealing; (2) the region of intermediate strain, characterised by the formation of large crystals on annealing. This is confined to a relatively small area, and is due to the fact that in this region some of the crystals are sufficiently strained to grow at the expense of their neighbours. Their neighbours have also been strained, but insufficiently to enable them either to grow or recrystallise; (3) the region of greatest strain, where recrystallisation and consequent refining followed by growth takes place on annealing. Recrystallisation takes place in the way shown by Chappell and confirmed by the present research. The position of the large crystals in relation to both of the other regions is determined by the annealing temperature. Region (1) is larger the lower the temperature, and both (2) and (3) are reduced correspondingly. The temperature also determines the size of the recrystallised and large grains. A point which is very clearly brought out by these experiments is that the large crystals are always formed *within* the strained region and not at the boundary of the stressed and unstressed areas.

Further information has been obtained on the relationships which exist between deformation, temperature and crystal size by carrying out some experiments similar to those described by Seligman and Williams. The material used was commercial aluminium sheet ¼ in. thick. The size of the test-pieces was the same as was used by Carpenter and Taverner. They were first annealed at 550 deg. C. for six hours. As the metal showed no change on annealing for further periods, it was considered that equilibrium had been reached in that time. This is reverted to later. The test-pieces were then pulled to different extents, and the elongation measured over 3 in. The first was given an elongation of 2 per cent., and each succeeding test-piece 2 per cent. more than the last, up to the breaking stress, when the elongation was 31 per cent.

The load required to give these permanent extensions was also noted. It increased quite regularly up to 10 per cent. extension, and was then almost constant at 5·44 tons per square inch up to 18 per cent., when there was another rise to 5·76 tons per square inch, which was also the breaking strain. This is shown more clearly in the accompanying diagram, No. 10, where the load in tons per square inch is plotted against the percentage elongation. The break at 5·44 tons per square inch corresponds to a drop in the beam when a test-piece of this material is pulled in the ordinary way. The yield point, as shown by placing dividers in the guage marks and noting at what load the stretch began, was 1·2 tons per square inch. A complete set of these test-pieces was afterwards broken. The results calculated on the new area showed an increase in strength, with breaks in the curve corresponding to similar breaks in the elongation load curve. If calculated on the original area, i.e., ½ sq. in., there was no increase in strength. These curves are all plotted together in diagram No. 10.

(To be continued.)

CRYSTAL GROWTH AND RECRYSTALLISATION IN METALS.

FIG. 34. Aluminium annealed 3 hours at 300° C. ×500.

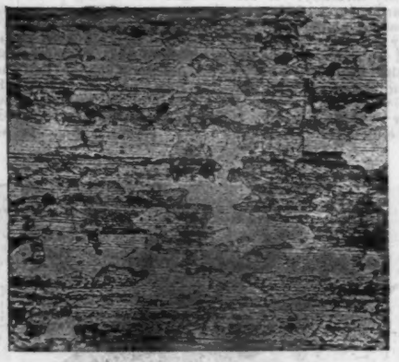


FIG. 35. Aluminium annealed 7 hours at 300° C. ×100.

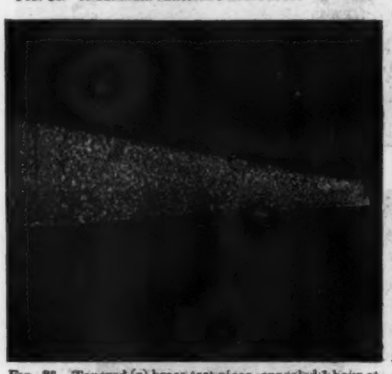


FIG. 36. Tapered (a) brass test piece, annealed 1 hour at 750° C. Natural size.

FIG. 37. Ditto, annealed 1 hour at 550° C. Natural size.

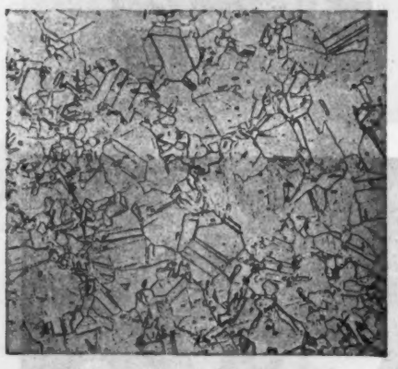


FIG. 38. Region of large crystals in tapered (a) brass test piece. 15 minutes at 750° C. × 75.

Reduced by one-sixth.

DIAGRAM No 9. DIAGRAM OF TAPERED TEST-PIECE

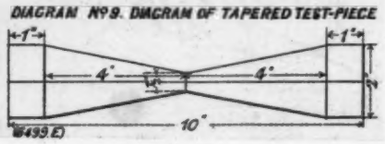
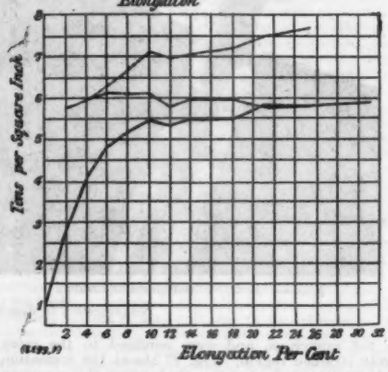


DIAGRAM No 10.

Maximum Stress. New Area.
Ditto Ditto Original Area.
Load required to give percentage Elongation.



ALLOTROPIC LEAD.—In 1915 H. Heller observed that compact lead, kept in lead acetate solution acidified with nitric acid, crumbled after several days into a grey crystalline powder. E. Cohen and Heldermann, of Utrecht, confirmed the experiments and regarded the crumbled lead as an allotropic modification of the metal; in fact, they found several modifications. Cohen, it will be remembered, first made an exhaustive study of the "tin pest," and later claimed to have established the allotropy for several other metals. A. Thiel, of München, repeating Heller's experiments last year, explains the supposed allotropy by chemical changes (*Berichte Deutsche Chemische Gesellschaft*, 1920, pages 1032 to 1066 and 1066 to 1072), which Cohen excluded as impossible. Thiel observed that the crumbling took place only in the presence of nitric acid, that both nitrogen and nitric oxide were evolved, that some lead was dissolved, and that the change was apparently due to the dissolution of the eutectic which, as in other compact metals, binds the crystalline grains of lead; the acid solution then penetrated into the compact metal and "disglomerated" it. He also accounted for the formation of a lead tree by immersing lead in solutions of certain lead salts, which Senderens had regarded as confirming that there were several allotropic modifications of lead. Thiel's lead was a water-pipe metal, which he found exceptionally pure, containing only traces of iron. He may not be right in asserting that the change required the presence of nitric acid; the attack might be more general, though lead is particularly soluble in nitric acid. But one can only wonder that Cohen should expect lead to remain chemically unchanged when exposed to the action of acid salt solutions for long periods.

HYDRAULIC-FILL DAMS.*

By ALLEN HAZEN, M.Am.Soc.C.E.

(*Continued from page 375.*)

The Determination of the Percentage of Voids.—This is a very simple matter, but experience shows that it is easy to go wrong, and for that reason a brief statement of methods that have been found suitable will be given.

The samples taken from the bottom of test borings are saturated with water. A determination of water content, therefore, can be made a measure of voids. This procedure is sound so far and only so far as the voids are completely filled with water. A useful check can be obtained from the specific gravity of the moist material.

The specific gravity of the solid particles of core material may be taken as 2·65. It may be that in some locations other specific gravities will be found, but in the writer's experience, actual values differ little from this mean value.

In determining the specific gravity of these exceedingly small particles, the most careful manipulation is required to get all the air out of the dry material. Methods similar to those used for determining the specific gravity of Portland cement are appropriate, but water can be used.

A table can be made showing the weight of the solid particles, the weight of water, the percentage of water by weight, and the specific gravity of core material containing various percentages of voids. Table I, in convenient and somewhat condensed form, gives these values for saturated clay.

When a sample is taken from a test boring, a portion is put in a dish and weighed. The weighed material is dried at or above the boiling point to constant weight, and the percentage of moisture computed. As even a little drying before the first weight affects the result, the samples should be weighed on the spot when first brought to the surface; to do this, portable equipment must be used. After the first weighing, samples may be taken to the office or laboratory for the completion of the process. When the percentage of moisture by weight is found, the corresponding percentage of voids is obtained from Table I.

As a check, the specific gravity of another part of the sample is determined. This is obtained by putting a weighed portion of the moist mass into a graduated cylinder partly filled with water and noting the increase in water level. The specific gravity is the ratio between the weight of material added and the weight of the water that corresponds to the increase in level, and so to the volume of material placed in the cylinder. With this specific gravity determined, Table I indicates the percentage of voids.

The percentage of voids determined by the two methods with good manipulation should check within 1 per cent. or 2 per cent. If it does not, there is something wrong and the error must be found and eliminated.

To determine the weight of the coarse and hard toe material, no better method has been found than to make an excavation accurately to a dimension of 1 cub. yard, or other convenient size, and to weigh the excavated material on platform scales. Percentages of moisture vary, and the weight of dry material affords the best basis of comparison. An average sample of material on the scales is taken for determining the percentage of moisture, and the results are reduced to weight of dry material per cubic foot.

Draining Fine Material.—The writer is fully satisfied that there is no practical way of rapidly draining core material as fine in grain size as that described previously. He has considered it from a theoretical standpoint and also from the standpoint of practical experience.

After the material reaches a condition of 50 per cent. of voids, 6 cub. yards must be compressed into 5 cub. yard of 40 per cent. material by the exclusion of 1 cubic yard of water before full stability can be counted on. This water, amounting to one-sixth of the whole volume of core material, must be expelled. The computed rate of flow through material with an effective size of 0·002 mm. is very slow. The rate depends on, and is proportional to, the hydraulic slope. With a slope of 10 per cent. (which is as steep as is usually found) the computed rate of flow as a solid column of the full area of the section is 0·32 mm. daily. At this rate, 80 days are required for the water to move 1 in. and 2·6 years for it to move 1 ft. This calculation cannot be used with assurance as establishing the exact rate of flow, but it is the writer's judgment that the actual rate is as likely to be below as above the result given. It is clear that, for a large dam, complete drainage and consolidation may be a matter of many years.

From a practical standpoint, it may be recorded that a 6-in. well driven 60 ft. in saturated core material having voids averaging 50 per cent., with the casing perforated freely to admit water, stood empty for weeks. Not enough water drained from this material to raise the water in the well. This may represent the effect of capillarity. With such a degree of tightness, it is clearly useless to attempt to secure consolidation by any method depending on additional drainage outlets.

Measuring Core Pressures.—An interesting method of measuring the pressures actually existing in core materials has been suggested by A. T. Goldbeck, Assoc. M.Am.Soc. C.E.* By this method, small test cells are built into the core material. Some are placed with horizontal and some with vertical faces, arranged to indicate pressures on the faces during construction and afterward. Such devices are reported to have been placed in hydraulic-fill dams now building by the Miami Conservancy District. The results of observation through a certain period have already been recorded. These observations indicate, as would be expected, that the horizontal and vertical pressures are the same at first and until the material has become somewhat consolidated. Afterward, horizontal pressure increases less rapidly than vertical pressure, and the inference may be drawn that this represents solidification of the material in which the cells are placed, to a point where the full horizontal pressure is no longer produced.

This is certainly an interesting method of test and one that may throw light on the conditions of core material.

It reminds the writer of one of his early experiences, which related to different circumstances, but possibly the same underlying principles are involved. It was proposed to build large and heavy structures in which the weight would be well distributed on a foundation of stiff silt. The question was presented as to whether the foundation was sufficient to carry the weight. An apparatus was provided by which test areas of 1 sq. foot at the level of the proposed foundation were loaded. The results of the tests were most satisfactory. The material carried more than the expected loads, with only insignificant settlements. When the actual structure was built, however, there was considerable settlement. The actual settlement was many times greater than has been indicated by the tests.

The explanation is simple enough. The single square foot that was loaded distributed the weight applied to it to a much larger area a short distance below. What was loaded was in effect a pyramid with a flat top of 1 square foot. The full applied weight per square foot was carried only at the top, and the unit stress became less going downward as the area of the pyramid increased. A thin layer of material just below the footing actually got the pressure and was compressed accordingly, and in this way the slight observed settlement was produced. Lower down, however, the unit pressure was lower and there was no appreciable compression.

When the structure was built there was no chance for a corresponding distribution of pressure. The whole area underneath was loaded, and the weight had to be carried through the full depth of silt and the silt was compressed. A corresponding settlement would no doubt have taken place in the test apparatus if the material loaded had been a column 1 foot square all the way down to rock. The writer thinks that because of this dispersion of load it is generally true that a small test area will carry more per unit than a larger one, and it may be that the same conditions will be found to apply to the test cells built into the core of a dam.

In view of all the information now available, the only safe course to follow, so long as the core material is like that here described, is to assume that it will produce the full horizontal pressure corresponding to its weight and height; and the toes must be made large enough to resist that pressure with ample safety.

TABLE I.—*Saturated Clay.**

Specific Gravity of Solid Particles, 2·65.

Percentage of Voids.	Percentage of Water, by Weight.	Specific Gravity, Wet.	Weight per Cubic Foot.	
			Wet.	Dry.
40	20·1	1·990	124·2	99·2
41	20·8	1·974	123·1	97·5
42	21·5	1·957	122·1	95·9
43	22·2	1·940	121·1	94·2
44	22·9	1·924	120·0	92·6
45	23·6	1·908	119·0	91·0
46	24·3	1·891	118·0	89·3
47	25·0	1·874	117·0	87·6
48	25·8	1·858	116·0	86·0
49	26·6	1·841	115·0	84·3
50	27·4	1·825	114·0	82·7
51	28·2	1·808	112·9	81·0
52	29·0	1·791	111·9	79·3
53	29·8	1·775	110·8	77·7
54	30·6	1·759	109·8	76·0
55	31·5	1·743	108·7	74·4
56	32·4	1·726	107·6	72·8
57	33·5	1·709	106·6	71·1
58	34·2	1·692	105·6	69·5
59	35·1	1·676	104·5	67·8
60	36·1	1·660	103·5	66·1
61	37·1	1·643	102·5	64·5
62	38·1	1·626	101·5	62·8
63	39·1	1·609	100·5	61·2
64	40·1	1·593	99·5	59·5
65	41·2	1·577	98·5	57·8
66	42·3	1·560	97·4	56·2
67	43·4	1·543	96·4	53·5
68	44·5	1·527	95·4	52·9
69	45·6	1·511	94·4	51·2
70	46·8	1·495	93·4	49·6

* This table is not to be used for any material that has lost water by evaporation so that the voids are not completely filled with water.

Resisting the Pressure of the Core Material.—The first point to be considered is the coefficient of friction of the material in the toe, sliding either upon the foundation or upon itself. With hard, clean gravel a coefficient of 0·7 or 0·8 might reasonably be expected, although the data for establishing this coefficient are not as convincing as could be desired. No such coefficient was found, however, in accounting for the Calveras slip. Instead, it was estimated that the weight of the material pushed forward in the up-stream toe was five times as great as the pressure of core material against it. In estimating that pressure the whole height and weight of core material was included, assuming that it acted as a heavy liquid. This indicated a coefficient of friction of only 0·20. This is to be taken as an average for the whole area on which the slip occurred. It may be recorded, however, that a similar calculation for the lower toe which did not slip indicated a coefficient of 0·22. No one can tell how much more it would have held.

The Calveras material is softer and perhaps more slippery than the hard particles of glacial drift of the Eastern States; and it would not be reasonable to expect as high a coefficient of friction. It may be, also, that the coefficient of friction under such heavy pressures as are found in the lower part of a high dam will be less than under the small pressures of moderate depths.

Some experiments were authorised by George Wilhelm, M.Am.Soc.C.E., and made by G. W. Hawley, M.Am. Soc.C.E., resident engineer at the San Pablo Dam, near Berkeley, Cal. (see Fig. 7), following suggestions of the writer. A 14-in. cast-iron pipe was cut into two short parts, one of which was fixed and the other attached securely to a steel frame which swung freely on an axis about 8 ft. above. Another steel frame securely connected the ends of this axis with the fixed part of the 14-in. pipe and with other parts of the apparatus. Two hydraulic jacks were used and the pressures were computed from the measured pressures on the pistons.

The two pieces of 14-in. pipe were placed in line and the frames held them so that the ends would just clear.

A sample of the material to be tested was placed in the pipe, filling the lower or fixed part and extending some distance into the movable part. Oak planks, cut to fit as a loose piston, were then placed above. One of the hydraulic jacks was placed above it. Pressure was then

FIG. 7. SAN PABLO DAM, SHOWING DEVELOPMENT OF LOW TOE, WITH THE FINER MATERIAL PASSING OVER IT TO THE CENTRAL POOL.

* Paper read before the American Society of Civil Engineers.

* *Engineering News-Record*, April 18, 1918, page 758.

applied to compress the material in the pipe to any desired extent. Experiments were made with various pressures, the greatest corresponding to a depth of fill of 200 ft. While the material was held under this pressure, the other jack was placed horizontally against the side of the 14-in. pipe with suitable blocking, and pressure applied until there was movement. The ratio of pressures on the two jacks then gave the coefficient of friction.

The steel frame and the pivot at the top was built so that there was no appreciable friction in the apparatus. A slight correction was necessary because the lever arm to the slipping plane was longer than the lever arm to the point on the 14-in. pipe where pressure was applied.

The form of the experimental apparatus was suggested to the writer by a paper by Mr. A. L. Bell on clay pressures.* The apparatus as worked out was more like that used by E. P. Goodrich,† M.Am.Soc.C.E., in his experiments on soil pressures.

The apparatus used differed from both of its predecessors in that tests were made at very much higher pressures. The results may be compared, but it must be remembered that the local material had peculiarities of its own, and that it was no doubt quite different physically from the material tested by Bell and Goodrich.

The writer will not attempt to discuss this matter further, but suggests it as a fruitful topic for further experiment.

Experiments were made by Mr. Hawley with various local materials at various pressures. These showed that, with low pressures, the coefficeint of friction was distinctly larger than it was with higher ones. The explanation for this may be that the higher pressures broke down and crushed the particles, and so reduced the relative resistance. After a certain pressure was reached there was less rapid change in the coefficients, and for the higher pressures the coefficients for any material were practically constant.

For material from the local soft sandstone rocks at San Pablo, coefficients of friction of approximately 0·5 were found.

There was one kind of material more slippery than the others for which an average coefficient of 0·45 was found. Other harder materials gave coefficients of 0·55 and more. Sand and gravel from the creek representing the remnants of much harder rocks in the hills (and so corresponding more nearly to the glacial drift of the Eastern States) gave coefficients of about 0·7.

The materials at San Pablo are similar to the materials at Calaveras; and there is reason to think that the coefficients found at San Pablo would apply approximately to the Calaveras materials.

What then is the explanation of the fact that the Calaveras Dam slip indicated a coefficient of 0·2 while similar materials in the test apparatus show a coefficient of 0·5—two and one-half times as much.

The answer seems to lie in the fact that in the course of construction at Calaveras, before the dam was very high, the construction pool in the centre of the dam was sometimes quite wide; so that at some levels the greater part of the width of the dam was composed of fine-grained core material. Afterward the proportion of solid fill was increased and the width of core reduced but the effects of the wide pool may have been permanently left in layers of core material extending far out under the more solid parts of the toes.

It seems probable that unstable core material placed in this way furnished the lubricant that facilitated and made possible the slip in the dam.

Section of Dam Required with Core Material Considered as a Fluid.—At Calaveras, the toe material was slightly heavier per cubic foot than the core material. At San Pablo, with fragments of porous sandstone rock predominating in the toes, there was scarcely any difference. With harder material like the glacial drift of the Eastern States, the toe material would be considerably heavier.

For the purpose of a first rough calculation, assume that the weights per cubic foot of toe and core material are equal, as they are at San Pablo. If a coefficient of friction of 0·5 is assumed, each toe must weigh twice as much as the pressure exerted by the core. The pressure exerted by the core is $\frac{1}{2}wh^2$ and the weight of the toe to balance it must be wh^2. To produce this weight, a uniform outer slope of 2 to 1 will suffice. In addition, a top width equal to the maximum width of core must be used. If a factor of safety of 2 is required, the outside slope must be made 4 to 1, but in view of the records of slips in actual dams, it may well take a higher factor of safety. A slope of 5 to 1 will give a factor of safety of 2·5 and a slope of 6 to 1 wil give a factor of 3. Where toe material is considerably heavier than the core, as would be the case with harder and heavier rocks, the slopes could be reduced in proportion to the increased specific gravity without reducing the factor of safety. Thus, with toe material 20 per cent. heavier than core material, a slope of 1 to 5 would allow a factor of safety of 3. Very few hydraulic dams have been built with sections as large as this line of thought suggests. The Gatun Dam at Panama heads the list, and is even larger.

A great many cubic yards are involved in such a large section, but if the work is done cheaply enough per cubic yard, it may be economical to use the extra volume. Safety can be secured in this way; and it may be that this procedure is the best one to follow.

TABLE II.—DIMENSIONS OF A NUMBER OF EARTH DAMS THAT HAVE STOOD SUCCESSFULLY.

Dam.	Height to Flow Line, H.	Area of Section, in Sq. Ft., A.	Ratio, $\frac{A}{H^2}$	Freeboard.	Width in Feet.				Bottom, W.	Ratio, $\frac{W}{H}$
					Top.	At Flow Line.	50 Ft. below Flow Line.	100 Ft. below Flow Line.		
*Gatun	78·0	99,200	16·30	20	100	397	1,460	—	1,990	25·5
*Big Meadows ..	64·0	24,300	5·93	20	30	180	460	—	548	8·56
*Coquitlam	83·0	38,700	5·61	15	40	145	521	—	702	8·46
*Cambria	82·0	31,200	4·65	13	20	98	429	—	685	8·34
Ashokan	90·0	35,400	4·37	20	34	112	400	—	650	7·23
Druid Lake	82·0	27,900	4·15	5	60	90	390	—	582	7·10
San Andreas	80·0	26,200	4·10	5	30	58	387	—	606	7·58
*Paddy Creek ..	120·0	58,200	4·05	25	23	161	414	664	757	6·30
*Somerset	92·0	33,200	3·94	13	25	78	375	—	616	6·67
San Leandro ..	65·0	16,350	3·88	5	30	56	335	—	457	7·04
*Halwee	75·0	21,600	3·85	14	20	90	340	—	465	6·20
Croton	96·0	33,400	3·62	24	30	126	336	—	528	5·50
Tabeaud	86·0	26,400	3·57	8	20	60	345	—	553	6·44
*Necaxa	164·0	90,800	3·36	16	54	136	386	636	954	5·81
Cold Spring	88·5	26,200	3·34	10	20	70	320	—	512	5·79
Belle Fourche ..	100·0	33,100	3·31	15	20	65	284	656	656	6·56
Lahontan	112·0	40,900	3·25	12	20	80	330	580	640	5·72
Santa Maria ..	85·0	23,500	3·25	8	20	60	310	—	485	5·71
Pilarcitos	74·0	17,600	3·22	5	30	56	288	—	415	5·61
Morris	90·0	25,700	3·18	9	20	60	309	—	502	5·58
Borden Brook ..	64·0	12,700	3·10	7	24	49	280	—	337	5·27
Honey Lake ..	90·0	25,000	3·08	6	20	50	300	—	500	5·56
Goose Creek ..	137·5	54,900	2·90	7	16	54	304	554	741	5·39

* Hydraulic fill, wholly or in large part.

Dimensions of a Number of Dams.—To see what these slopes would call for in the way of section in comparison with earth dams that have been actually built either by the hydraulic method or as dry fill, the following comparison is made. Assuming a freeboard of one-tenth the greatest depth of water, H, and a top width of 0·25 H and uniform slopes, the cross-sections of dams in terms of the greatest depth of water would be as follows:—

Slope.	Volume.
3 to 1	3·9 H^2
4 to 1	5·1 H^2
5 to 1	6·3 H^2
6 to 1	7·5 H^2

The actual dimensions of a number of dams are given in Table II.

Rock-fill dams are not included, but rock fill forms some part of a number of dams in the list. No dams holding less than 64 ft. of water are included.

The Necaxa Dam slipped, but was afterward rebuilt on the original section. The Big Meadows Dam is being raised with an enlarged section.

(To be continued.)

HYDRAULIC CENTRIFUGAL PUMPS FOR SHIP SALVAGE CRAFT.—Some centrifugal pumps recently built by the firm of Weise Söhne, of Halle, for the German Navy salvage boats, are driven by water turbines working at pressures ranging from 6 to 10 atmospheres. The water discharged by the turbine enters the diffuser of the pump, so that the useful head of water is diminished by the counter-pressure of the pump. Together with its suction case a pump of maximum diameter of 265 mm. (10·5 in.) weighs 49 kg. (108 lb.), the maximum height being 0·6 m. (23·6 in.). The pumps are portable, and are said to be of relatively high efficiency; owing to their small diameter they can be pushed into the wreck through the port holes, and they are less sensitive than electric pumps. The efficiency falls off, however, when the working pressure of the water fluctuates, which it is apt to do when the water is supplied by piston pumps.

* Minutes of Proceedings, Inst.C.E., Vol. cxcix 1914–15), page 233.

† Transactions Am. Soc.C.E., Vol. liii (1904), page 297.

CATALOGUES.

Oil Power.—Messrs. Plenty and Son, Limited, Newbury, in the July issue of their journal *Oil Power*, publish informing articles on oil fuel, governor gear for marine oil engines, and various kindred matters.

Electric Circuit Breakers.—The British Thomson-Houston Company, Limited, Rugby, has issued a 24-page descriptive catalogue of their automatic circuit breakers for alternating and direct current circuits with their usual clearly tabulated particulars.

Small Tools.—The Brooke Tool Manufacturing Company, Limited, Warwick-road, Greet, Birmingham, has now issued in a single well arranged volume the catalogues recently noticed in these columns, covering a very complete range of cutting tools, gripping devices, &c.

Electric Switches.—The sole selling agency in this country for the Hart rotary type snap switches made in the United States by the Hart and Hegeman Company, has been taken up by the General Electric Company, Limited, 67, Queen Victoria-street, London, E.C.1, who have issued a special catalogue giving particulars of numerous types made.

Arc Welding.—A very complete and instructive catalogue has been issued by the British Arc Welding Company, Limited, Glengall-road, Millwall, London, E. 14, giving an explanation of the principles of this system with practical advice, figures of tests, and illustrations of special work done. The necessity for careful operation and well trained workmen is frankly stated, and the catalogue as a whole is of the useful kind.

Vertical Steam Engines.—Messrs. Peter Brotherhood, Limited, Peterborough, send a catalogue of vertical steam engines for driving dynamos, circulating pumps and forced-draught fans. All types and each of the principal parts are illustrated and described. Tables of standard sizes made include single, tandem, compound engines, and two-crank compound engines, the range of powers running from 2½ brake horse-power up to 950 brake horse power. The powers are given for various steam pressures and all necessary particulars are carefully stated.

Gas Boosters.—The distribution of gas at high pressure in the main lines as an alternative to laying larger mains has been specially studied by the Bryan Donkin Company, Limited, Chesterfield, who send a new catalogue of 68 pages explaining the systems they have installed and the machinery made by them which include fans, blowers, and compressors with turbine and reciprocating engines and a large variety of governors and other regulating appliances. An important secondary result of this system is that it enables gas generating works of large capacity to supply distant districts which would otherwise need small local gas works of a necessarily less economical type. The catalogue is of exceptional interest.

Steam Boilers.—A new edition of their catalogue of boilers issued by Messrs. Marshall, Sons and Co., Limited, Gainsborough, contains descriptions of locomotive-type boilers ready for use without requiring buildings, or mounted on wheels for easy transport from place to place by road. Other types have large cylindrical fire-boxes for burning waste wood, &c., and additional fronts are fitted if the waste is more bulky. Vertical boilers are made in two types, and a special "dredger" boiler for use where only bad feed water is all that is available. All necessary fittings are included in the catalogue, also oil-burning apparatus. Several of these special forms are chiefly used overseas under special conditions for which they are particularly designed. A four-page catalogue illustrating a great variety of engines and boilers has also been issued.

Steam Turbines.—Messrs. Fraser and Chalmers, Limited, Erith, Kent, who have had a wide and continuous experience of steam turbine making, have issued a catalogue containing a clear and practical history and explanation of the turbine and a description of their machines as now made in the five types in which turbines are now generally defined; viz., high, low, mixed, back and reducing. The turbines are used for driving electric current generators, blowers, compressors, and pumps in large direct coupled units and, in reduction gear, for mill driving in addition to ship propulsion. The catalogue is really a general introduction to the subject as, of course, in such large machinery nearly every installation is to some extent specially designed. The General Electric Company, Limited, with whom Messrs. Fraser and Chalmers are now associated, also send a similar catalogue with the addition of special matter describing the electric generators.

Oil Engines.—The oil engines made by Messrs. Sulzer Brothers, Winterthur, Switzerland (31 Bedford-square, London, W.C.1) are described with some interesting technical discussion in several catalogues dealing principally with marine engines and including those termed "auxiliary," which, in this case, means auxiliary to the sails of a sailing ship. Much importance is attached to the development of the two-cycle engine, and the advantages in construction, operation and capital cost are strongly emphasised. At cruising speed the two-cycle engine is claimed to be more economical than the four-cycle type. The largest field for these engines seems to have been found in small craft and in the smaller ocean-going cargo boats. The relative weights of the total marine machinery are given, in one instance, as: Four-cycle, 1,263 tons, two-cycle, 775 tons, and space required for the latter is, of course, much less. The strongest point, in the matter of space, in favour of the two-cycle engine is that the height required is much less than that necessary for a four-cycle engine.